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ASSESSMENT OF THE COST OF REDUCING
RISK IN INDUSTRY AND TO SOCIETY

by

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ABSTRACT

The purpose of this project is to derive empirical estimates of how much Canadian industry and society in general tend to spend for the reduction of non-radiological health risk. Five case studies were selected for detailed analysis including cervical cancer screening in British Columbia, rail crossing signal improvement in Ontario, oil and gas drilling accident reduction in Alberta, reduction of occupational exposure to lead in Ontario and the purchase and use of children's automotive seat restraints. Estimates of risk reduction were derived from available data bases maintained by responsible federal and provincial agencies. Estimates of expenditures and details of decision making processes underlying expenditure decisions were obtained by personal interview process. Results, in terms of expenditure per unit risk reduction, were prepared using these estimates. The results illustrate a wide range of definitions of risk and expenditures per unit of risk reduction. The study identifies methodological constraints in deriving such estimates and highlights considerations and directions for future research. The study concludes that there is no one measure of spending for risk reduction but a spectrum of such measures. Further estimation of these measures is feasible but should be restricted to cases where confounding factors are minimized or absent.

Based on the case studies selected for this project it is concluded that there are likely to be very few ex post examples of risk reduction which fulfill this requirement.

RÉSUMÉ

Le présent projet a pour but de dériver des estimations empiriques des sommes que l'industrie et la société canadienne en général est prête à dépenser pour réduire les risques non radiologiques pour la santé. Cinq études de cas ont été choisies pour être analysées en détail, y compris le dépistage de cancer du cerveau en Colombie-Britannique, l'amélioration de la signalisation des passages à niveau en Ontario, la réduction des accidents dus aux forages de pétrole et de gaz en Alberta, la réduction des expositions professionnelles au plomb en Ontario, ainsi que l'achat et l'utilisation de sièges de sécurité pour enfants dans les voitures. Les estimations de réduction de risque ont été dérivées de banques de données des organismes fédéraux et provinciaux responsables. Les estimations de dépenses et les détails des processus décisionnels sous-jacents aux décisions de dépenser ont été obtenues par des entrevues personnelles. Les résultats exprimés en fonction des dépenses par unité de réduction de risque, ont été établis à partir de ces estimations. Les résultats illustrent une grande variété de définitions du risque et de dépenses par unité de réduction de risque. L'étude indique les contraintes méthodologiques associées à la dérivation de telles estimations et fait ressortir certaines considérations et directions pour des recherches ultérieures. L'étude conclut qu'il y a vraiment plus d'une mesure de dépense pour réduire le risque. D'autres estimations de ces mesures sont faisables, mais devraient être limitées à des cas où les facteurs d'ambiguïté sont minimisés ou absents.

D'après les études de cas choisis pour le présent projet, le rapport conclut qu'il y a sans doute très peu d'exemples en rétrospective qui satisfont cette exigence.

DISCLAIMER

The Atomic Energy Control Board is not responsible for the accuracy of the statements made or opinions expressed in this publication and neither the Board nor the author assumes liability with respect to any damage or loss incurred as a result of the use made of the information contained in this publication.

PREFACE

This Project has been completed with the assistance of representatives of a large number of government agencies and private sector firms. The contributors are too numerous to acknowledge here individually but our appreciation is extended to all who assisted. With the exception of private firms, to whom confidentiality was assured, key contributors are cited at the end of the case studies described in this report.

This Project presents the results of a unique analysis of expenditures for risk reduction in Canada. We would also like to acknowledge the assistance and cooperation of the AECB Scientific Authority in carrying out this assignment.

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EXECUTIVE SUMMARY

PURPOSE OF THE STUDY

The primary purpose of this project was to obtain empirical estimates of how much Canadian industry and society in general tend to spend for the reduction of non-radiological risk. In addition the project was to ascertain how decisions on risk reduction are typically made, including the methods and rationales underlying expenditure decisions.

Estimates of expenditures per unit risk reduction derived from society at large may provide useful benchmarks for determining what might reasonably and equitably be expected of radiation industries for control of radiation exposure under the regulation of the Atomic Energy Control Board of Canada (AECB).

The intent of the project was to measure risk reduction and associated expenditures in instances both inside and outside the workplace and for situations where both industry and society (either governments or individuals) were the primary decision makers.

The project was conducted over a period of one year by personnel in three offices of the DPA Group Inc., economic and management consultants. The remainder of this Summary outlines the approach, methods used, results, conclusions and recommendations arising from the project. Within the body of the main report full details of the case studies conducted are provided in chapters intended to stand alone as research reports.

APPROACH AND METHODS

Early in the project it was determined that a case study approach was desirable for the following reasons:

- i) It was apparent that a broadly based survey approach would not likely result in the depth of analysis required to substantiate results. Response rates to such surveys are typically very poor.
- ii) It was also apparent that in most instances a significant effort would be required to collect, analyse and interpret both risk and expenditure data for each individual case study. There was very little risk information that was available in a form that could be readily interpreted from a broadly based survey.

Given the adoption of a case study approach the following tasks were carried out:

- i) Criteria were defined for identification and selection of case studies. The primary criteria for selection were the presence of demonstrated evidence of risk reduction, clarity of cause-effect linkages, and accessibility of risk and expenditure data.
- ii) Prospective case studies were identified and evaluated according to the above criteria. Approximately fifty potential topics in nine topic areas were identified and assessed, primarily in terms of evidence of risk reduction. Although many topics appeared to be initially attractive on the basis of cursory familiarity, more intensive investigation revealed weaknesses in most topics which excluded them from adoption of case studies. Case studies were excluded for one or more of the following general reasons:
 - o clear quantifiable evidence of risk or risk reduction was not readily available
 - o cause-effect relationships were poorly understood
 - o scientific evidence of causality is weak
 - o time lags in manifestation of effect
 - o multiple cause-effect
 - o confounding concurrent factors
 - o unknown effects of chronic low-level exposure to hazards
 - o preliminary indication of a lack of industry support for the study (i.e. from discussions with industry associations)

A long-list of eight prospective case studies was established including:

- * rail crossing improvement
- visual flight rule (VFR) accident reduction
- reduction of trenching accidents in the construction industry
- * reduction of occupational exposure to lead
- * reduction of accidents in the oil and gas drilling industry
- * cervical cancer screening
- immunization (measles)
- tuberculosis testing

It was determined that four case studies could be completed within the original budget. Those studies noted above by asterisk (*) were selected on the overall basis of data availability, representation of different types of risk and decision stances, clarity of cause and effect and potential for industry participation.

At the request of the scientific authority an additional case study relating to individual decision-making was subsequently identified (*children's automobile seat restraint use) and additional budget provided to carry out the study.

- iii) Detailed methodologies for data collection and analysis were then developed for each case study. The specifics of these methods are reviewed in the Case Study Overview which follows.

Of particular note were efforts to standardize expenditure data in terms of a selected base-year and efforts to standardize risk data in terms of a unit size of the population at risk (e.g. 100,000 persons) or in terms of a unit measure of work (e.g. 1,000 man-hours) or in terms of a standard measure of inherent hazard (e.g. 1,000,000 units of rail-vehicle traffic).

A key aspect of our approach to collecting information, particularly from industry respondents, was that personal interviews would be required in order to encourage participation, confirm data, and elicit commentary on how and why risk reduction decisions were made. With respect to the industry-based case studies (lead exposure reduction and drilling accident reduction) invitations to participate were sent out by mail followed up by personal confirmation and a structured interview. Interview guides were prepared to ensure consistency of questioning.

- iv) Data were then collected and analyzed. Case studies were assigned to individual researchers who had a particular expertise and interest in the topic. Deficiencies and constraints of the data were noted as analyses progressed.

- v) Each case study was then written up as an individual report in a scientific research format. Conclusions and observations pertaining to the reliability of estimates of expenditure per unit risk reduction and to the rationales for decision-making were highlighted.

It is important to note that only a small proportion of potential case studies were found to fulfill the fairly rigorous criteria enforced. That is not to say that the excluded case studies, given significantly greater research effort, may not have yielded useful results, but that the probability of successful completion under the constraints of this study was low. It is also important to note that our identification of potential studies cannot be considered exhaustive but represents what was achievable within the period of time allocated to that task. It is likely that other candidates exist and that they may be identified over time.

OVERVIEW OF CASE STUDIES

Table 1 summarizes the pertinent characteristics of the selected case studies. The case studies cover a range of decision makers, types of risk and forms of intervention. Most of the studies are based on post-1970 data with an emphasis on the 1975 to 1985 period. The form of intervention is unique to each circumstance but most are characterized by an initial capital cost (e.g. setting up a laboratory, installing rail crossing signals, purchasing ventilation equipment) followed by an ongoing cost of operation and maintenance which is required to implement and sustain risk reduction.

Table 2 describes the units of risk used, data sources, methods of calculating risk reduction and methods of collecting expenditure data for the case studies. It is notable that the measures of risk adopted are largely incommensurate - that is, based on different units.

The problem of incommensurate measures of risk is inherent to any broadly based analysis of risk. Although it may be desirable to have a common unit of risk (e.g. mortality rate per 100,000 persons) under conditions of practical analysis this may not be possible for the following reasons:

- o the event or outcome being measured may not result in mortality (e.g. sub-lethal lead poisoning)
- o mortality events may be so infrequent and variable in magnitude that changes in mortality rates may be detected only with very large data bases or over very long periods of time (this was the circumstance in the child seat, rail crossing, and drilling case studies where mortality events were relatively rare and tended to occur on a group basis - i.e. 3 to 5 people killed in one event).

It is notable that 9 out of 66 invited firms decided to participate in the drilling industry case study and 10 out of 44 invited firms in the lead industry study agreed to participate.

TABLE 1 SUMMARY DESCRIPTION OF CASE STUDIES

	Cervical Cancer Screening	Rail Crossing Signal Improvement	Oil and Gas Drilling Accident Reduction	Reduction of Occupational Exposure to Lead	Children's' Automotive Seat Restraints
- location	British Columbia	Ontario	Alberta	Ontario	Alberta/Ontario
- type of decisionmakers	- provincial health authorities	- Canadian Transport Commission - municipal road authorities	- industry firms - provincial safety authorities	- industry firms - provincial safety authorities	- individual parents
- type of risk	- disease	- accident	- accident	- disease	- accident
- outcomes	- morbidity - mortality	- injury - fatality	- injury - fatality	- morbidity	- injury - fatality
- form of risk intervention	- cytological screening of female population plus treatment	- engineering improvements to level crossing signals	- worker safety training programs plus government inspection	- engineering and operating measures to reduce exposure	- purchase and use of protective car seats
- time frame of analysis	1958-1980	1971-1984	1963-1985	1976-1985	1977-1985

TABLE 2 SUMMARY OF CASE STUDY METHODS

	Cervical Cancer Screening	Rail Crossing Signal Improvement	Oil and Gas Drilling Accident Reduction	Reduction of Occupational Exposure to Lead	Children's' Automotive Seat Restraints
- Measure of risk:	- mortality	- accident rate	- accident rate	- blood lead con'cn	- major injury rate
units:	# of deaths per 100,000 female pop'n (20 yrs+ of age)	# of accidents per million product of rail x traffic volumes	# of accidents per million meters drilled	# of blood tests exceeding 7.7 mg Pb/l per 1000 workers tested	# of children (0-5yrs) sustaining major injuries per 1000 child-involve-ments in reported accidents
time basis:	annual	annual	annual	annual	annual
- source of risk data:	- Cancer Control Agency of British Columbia (CCABC)	- Canadian Transport Commission (CTC)	- Alberta Workers' Compensation Board	- Ontario Ministry of Labour	- Ontario Ministry of Transportation - Survey of Alberta Parents
- method of calculating risk reduction	- comparison of annual mortality rates 1958-59 and 1979-80	- analysis of accident rates 5 years before and 5 years after intervention	- analysis of annual accident rates 1971 to 1984	- comparison of annual blood con'cn test results 1981 to 1984	- comparison of annual injury rates (Ontario), restrained vs unrestrained 1977 to 1985
- method of collecting expenditure data:	- estimates provided by CCABC	- crossing cost data from CTC files	- interviews with 9 drilling firms estimates provided by gov't agency	- interviews with 10 lead producing/using firms - estimates provided by gov't agency	- Survey of perceived risk reduction (restrained vs unrestrained) - Interviews with 78 parents

SUMMARY OF RESULTS

Table 3 provides a summary of the results of the case studies. In interpreting the results the following key points should be borne in mind:

- 1) In two studies in particular, cervical cancer screening and rail crossing improvement, there was evidence of a concurrent downward trend in risk which was likely independent of the effect of the intervention under study. Removal of this independent trend would reduce the effective risk reduction attributed to the intervention and thus increase expenditures per unit risk reduction. It has not been possible to determine accurately the magnitude of these independent trends.
 - ii) The two industry case studies, oil and gas drilling industry and lead industry, are based on very small sample sizes (i.e. less than 10 firms each). Whereas the data on risk reduction for these studies were derived from industry aggregate data bases, information on expenditures came from the individual firms interviewed. The variability in these expenditure data is large and it therefore may not be appropriate to use the average values derived in this project to extrapolate to the industry as a whole. In addition, one must assume that the risk phenomena observed in the aggregate risk data are representative of the group of participating firms.
- It was apparent that those firms volunteering to participate generally had been particularly active in risk reduction. The expenditure data derived from these firms might be expected to be higher than the industry as a whole thus biasing upwards the estimates of expenditures per employee.
- iii) A number of factors unaccounted for in this study may have influenced the observed risk data. Although the case studies were selected for clarity of causality, amongst other criteria, it was apparent upon deeper investigation that there are inevitably an array of external factors that likely influence the risk measures. Without more extensive in-depth research the influence of these factors remains unknown (e.g. the effect of workforce age structure on drilling industry accident rates).
 - iv) Each study has been based on a unique as opposed to a common definition of risk; this approach was dictated by the data available and the unique underlying characteristics of risk and risk intervention. It is notable that in three of the case studies (rail crossing, drilling, and children's car seat) mortality or fatality data were considered to be too highly sporadic and variable to support demonstration of risk reduction. Therefore, accident rates were used as measures of risk in these instances.

TABLE 3 SUMMARY OF CASE STUDY RESULTS

	Cervical Cancer Screening	Rail Crossing Signal Improvement	Oil and Gas Drilling Accident Reduction	Reduction of Occupational Exposure to Lead	Children's' Automotive Seat Restraints
EXPENDITURES	\$13.1 million * \$34.3 million (1985\$)	\$3.3 million *	\$0.97 million* per million metres drilled	\$4.171 million (1985\$) per thousand employees	\$72 (1986\$) average actual expenditure per seat purchase
basis:	total screening costs: 1958 to 1979	total cost of 116 crossings upgraded between 1975 and 1979	average annual expenditures of 8 reporting firms post- 1978	average annual expend- itures per employee of 10 firms aggregated over 4 years: 1981 to 1984; expenditures 1981 to 1984	survey of 78 parents
RISK REDUCTION	8 deaths per 100,000 females (20+ years of age)	235 accidents over 5 year post-upgrade periods	range of 303 to 485 accidents per million metres drilled	31 excessive blood lead concentration tests per thousand employees	estimated reduction of 12.6 serious injury events per thousand accident involvements
time basis:	annual	annual	annual	annual	annual
basis:	mortality rate: 1958-59 vs 1979-80	total accidents: 5 yrs pre-upgrade minus 5 yrs post- upgrade	standardized accident rate: - actual vs predicted - pre-1977 vs post-1982	blood lead concen- tration test results - 1981 vs 1984	serious injury rates: Ontario 1977 to 1985
EXPENDITURE PER UNIT RISK REDUCTION	\$1,633,981* per unit reduction in mortality rate**	\$2,163,779* for reduction of 1 accident per 5 yr period (based on 1 x 10 ⁶ units of rail-vehicle traffic volume product)	\$2,000 to \$3,200 per million metres drilled for reduction of 1 accident per million metres drilled	\$135,000 for reduction of 1 excess blood lead concentration test per thousand employees	\$5.71 for reduction of 1 serious injury per thousand involvements
	\$4,286,883 (\$1985) per unit reduction in mortality rate				
	\$21,084* per life saved	\$14,173* per accident averted	\$2,000 to \$3,100* per accident averted		

* \$ of the year spent

** a unit reduction in mortality = 1 death averted per 100,000 females per annum

DISCUSSION OF RATIONALES FOR DECISIONS MADE ON REDUCTION OF RISK

A secondary but important objective of this study was the determination of rationales underlying decision making in the case studies. The most important perspectives derived from this component of the study are as follows:

- 1) With respect to government agencies there has been an increasing desire and tendency over time to develop logical, technically-based decision making aids (i.e. cost-benefit models, investment priorities models, cost-effectiveness analysis). Decisions made in the 1950's, for instance on cervical cancer screening, were generally based on the perceived merit of the risk intervention with little analytical testing. In the health sciences area epidemiological analysis and disease modelling have emerged as potent tools for governmental analysis of public investments in health protection. Our research in this study indicates, however, that these analytical tools are just now being considered as one form of input to funding allocation decisions. In general, pragmatic rules of thumb (e.g. for deciding which crossings have priority for improvement or how often cervical cancer screenings are recommended for women) are combined with normal socio-political forces to reach a decision on investment. There is significant latitude remaining for improving the technical basis for these decisions but such technical support is based on longer-term accumulation of evidence through scientific analysis.
- 11) With respect to industry decision making it is clear that each decision making unit has its own sets of priorities and its own capabilities for expenditures on workplace risk reduction. Whereas government regulation, including enforcement, is an important stimulus for action there are also other stimuli such as corporate goodwill, costs of compensation, media exposure, and labour relations. In some instances (e.g. oil and gas drilling accident increases on particularly severe railway accidents) there are unique events that precipitate a joint response of industry and government. In other instances there are gradual and incremental responses over time to an acknowledged problem (e.g. lead exposure). It is apparent now that within the workplace there is greater awareness of employee health and safety than ever before and that decision making is becoming more structured and open to review (e.g. joint workplace health and safety committees). Given the complexity of many contemporary health issues there is an ongoing requirement and impetus for improving the scientific basis for decisions on risk intervention. In many instances, particularly with respect to the effects of low level chronic exposure to hazards, it takes a long time to accumulate sufficient evidence to support decisions. The point at which evidence is deemed to be "sufficient" remains however a source of socio-political and scientific debate.

- iii) With respect to individual decision making, the relatively small investigation carried out in this study (child seat restraints) illustrates the relationship of perceived risk to actual risk as well as the apparent willingness to pay more for existing levels of protection or incremental levels of protection. It is also instructive to observe in this case that there is no tightly defined relationship between willingness-to-pay and perceived risk reduction (see children's seat restraint case study). This is likely a result of the lack of experience of consumers (i.e. of car safety seats) in differentiating risk and in relating such differentials to some value. The information base on relative risk (e.g. seat belts versus car safety seats) is often not available to consumers or interpretable by them. It is also apparent that there are no major manufacturers' initiatives in the area of children's car seats to differentiate their product on the basis of safety, but rather the intent appears to be to meet standards at lowest cost for a functionally and aesthetically attractive product.

CONCLUSIONS AND RECOMMENDATIONS

The essential conclusions arising from this study are as follows:

- i) There is no "one value" of expenditure per unit risk reduction which can be used to describe risk aspects of Canadian society. Expenditures per unit risk reduction, even if based on common risk denominators, can be expected to vary by several orders of magnitude amongst types of risk intervention and significantly even within a given class of intervention. Society is composed of a spectrum of risk and a spectrum of response to that risk - there are presently no rigid and universally constant rules defining that response but basic principles of cost-effectiveness are receiving greater attention as public and private expenditures for health and safety come under greater scrutiny.
- ii) Given this spectrum of risk it would in theory be possible to derive a distribution of expenditures per unit risk reduction. This has been attempted in other jurisdictions and would provide broad parameters and bounds to what might reasonably be expected or regulated in Canada. This study illustrates however that there are several methodological and practical constraints to deriving substantiated measures of expenditures per unit risk reduction, apart from solving the problem of finding examples with commensurate risk units.
- iii) After-the-fact measurement of risk is often very difficult due to the lack of statistical documentation of risk, lack of clarity in cause and effect related to both risk and risk intervention, and a lack of control for concurrent trends. These problems lead to the conclusion that risk analysis must be designed and implemented early for a specific purpose and must be based on scientific monitoring procedures.
- iv) This study is not based on a completely exhaustive search for clearly-defined candidates for risk analysis. It is likely, given the pervasive nature of risk, that other good case study candidates exist. From the experience gained in this study, examples from the health sciences, transportation, and consumer products fields are most likely to provide tractable studies.
- v) There are major practical problems in obtaining the participation of industry and collection of consistent information from industry to support analyses of expenditures per unit risk reduction. This study has demonstrated that such problems can be overcome but at significant cost; it should also be recognized that voluntary industry participation likely involves significant bias in results. It should not be expected that industry participation rates will exceed 25% of invitees. With this constraint in mind it is important that researchers enter longer-term research partnerships with industry particularly in the areas of cost-effectiveness analysis of risk intervention and cost-of-compliance analysis.

- vi) Given the effort to collect, analyse and interpret risk and expenditure data we believe that the case study approach is confirmed by this study to be the best approach to obtaining estimates of expenditure per unit risk reduction.
- vii) Given the above noted caveats we believe that this study has documented both the complexity of risk-expenditure analysis as well as the feasibility, under specific conditions, of obtaining quantitative estimates. Analysis of the degree to which decisions are based on objective grounds (i.e. a logical decision making structure based on fact) as opposed to subjective grounds (ie. based on opinions or positions unfounded in fact) was attempted in a qualitative sense in this study. A more quantitative assessment of this question would require more extensive application of social science research tools (e.g. statistically valid survey techniques and multivariate analysis methods).
- viii) Finally it is concluded that significant gains in terms of efficient allocation of societal resources may be achieved through assessment and comparisons of investments in health and safety risk reduction, where sufficient data are in place and where commensurate measures of risk are in place.

The recommendations emerging from this study are as follows:

- o Should the AECB wish to acquire further estimates of expenditure per unit risk reduction, we recommend that further case studies be conducted in the fields of health science, transportation and consumer products safety.
- o The collection of defensible estimates of expenditure per unit risk reduction would be enhanced by an organized long term research program in risk expenditures and risk-benefit analysis. Should such a program be considered we would recommend that the AECB involve other federal and provincial government agencies with mandates for public health and safety to ensure collection and exchange of information in a desirable form and efficient allocation of research effort.
- o We recommend that future efforts to calculate expenditures per unit risk reduction should, of necessity, use common commensurate measures of the risk denominator (e.g. mortality rate per 1,000 individuals; lives saved). Situations of long-term exposure with lagged effect which are comparable in type to radiological risks would also be desirable. These situations severely restrict the types of cases that may be analysed but ensure comparability of results.

PART A - BACKGROUND, CONCEPTS AND APPROACH

Purpose and Overall Scope of the Project

Approach to the Project

Selection of Case Studies

PART A - BACKGROUND, CONCEPTS AND APPROACH

1. PURPOSE AND OVERALL SCOPE OF THE PROJECT

The Atomic Energy Control Board of Canada (AECB) has the legislated responsibility for regulation and control of the development, application and use of atomic energy in Canada and participates on behalf of Canada in international measures of control.

The AECB achieves its control through a comprehensive licensing and standards system that covers all aspects of nuclear facilities, prescribed substances and equipment to assure that proper consideration is given to health, safety and security.

The AECB Regulations prescribe in Schedule II the "maximum permissible doses" of ionizing radiation generally, and also the "maximum permissible exposures to radon daughters". The limits specified are based on biological and scientific information and advice collected and analyzed over many years, and much weight is given to the recommendations of international bodies, in particular the International Commission on Radiological Protection (ICRP), formed in 1928. The AECB assumes that there is no threshold below which there are no harmful effects and subscribes to the principle that all doses should be kept "as low as reasonably achievable, social and economic factors being taken into account".¹

The ICRP has issued recommendations for basic principles which are the basis of a system of dose limitations (ICRP 1977). In addition to the principle of maintaining doses as low as reasonably achievable, ICRP recommended that "no practice shall be adopted unless its introduction produces a net benefit". Furthermore ICRP recommended that

"in order to determine whether a reduction in exposure is "reasonably achievable" it is necessary to consider on the one hand the increase of benefit from such a reduction and on the other the increase of cost involved in its achievement."

This comparison of net benefit at different levels of protection may be conducted by differential cost-benefit analysis. In order to facilitate the application of differential cost-benefit analysis to the optimization of radiation protection, a value is needed for the minimum amount that should be spent for unit reduction in dose. This minimum amount, expressed, for example in dollars per person-sievert, is commonly called "alpha". Alpha values have been derived by other countries by various methods from assessments of how much society tends to spend to reduce risk in various activities. It is

¹ Much of the above description of AECB mandate and activities is abstracted from the Annual Report of AECB 1984-85.

desirable to obtain Canadian data on how much industries and society in general tend to spend for non-radiological risk reduction.

This project was therefore commissioned by the AECB with the primary objective of determining how much industry and society in general tend to spend for non-radiological risk (fatal and non-fatal) reduction, and the methods and rationale behind the dollar decisions.

Preliminary discussions indicated that the project should focus on the quantitative measurement of expenditures per unit of risk reduction.

The scope of the project was defined to include the following elements:

- (i) expenditures by industries to reduce non-radiological risks in the workplace;
- (ii) expenditures by industries to reduce non-radiological risks to society; and
- (iii) expenditures by Canadian society (including government) to reduce non-radiological risks.

The scope was originally restricted to the province of Ontario and the time period 1979 through 1983. After consideration of suitable examples for study, these boundaries were determined to be overly restrictive and were relaxed to allow examination of Canadian examples over any well-documented period of time.

Additional aspects of scope agreed upon early in the project include the following:

- o the project should cover a range of risk and risk reduction expenditures but emphasis will be given to those cases where risk information is readily available in desired format.
- o the project should examine accidents and resulting injury as well as long-term degenerative diseases and illnesses.
- o representative examples of expenditures per unit risk reduction are desired.

2. APPROACH TO THE PROJECT

Early in the project it was decided to use a case study approach to collecting the necessary information. This approach allowed the researchers to identify specific examples of expenditures for risk reduction where there was a high likelihood of obtaining useful and defensible results. The alternative of a broadly based comprehensive industry and government survey technique was considered to have serious disadvantages in terms of:

- o a lack of focus on demonstrated areas of risk reduction and subsequent inefficient and diffuse use of project budget.
- o a high probability of low response rates.
- o a reduced capability to adequately research cause-effect linkages related to risk and risk intervention.

Once the case study approach was elected the following tasks were carried out:

- (i) Criteria were defined for identification and selection of case studies.
- (ii) Prospective case studies were identified (i.e. long list) and evaluated according to the defined criteria.
- (iii) Selected case study topics were subjected to a more vigorous feasibility assessment. Five case study topics were chosen for detailed study (i.e. short list).
- (iv) Methodologies for data collection and analysis were designed for each case study.
- (v) Data were collected and analysed. Deficiencies and constraints of the data were noted.
- (vi) A final report was written and subjected to critical review.

In carrying out these tasks two important goals were borne in mind. First, that the results of the project be as scientifically defensible as possible and, second, that the cooperation of those firms and agencies providing information be maximized. The selection of case studies and design of data collection and analysis methodologies were therefore carried out to optimize the fulfillment of these goals.

The following section describes the process by which case studies were selected. In Part B of this report the details of each individual case study are presented.

3. SELECTION OF CASE STUDIES

3.1 Criteria for Selection

The following criteria were developed to permit identification and evaluation of prospective case studies:

- (1) Evidence of risk reduction: There must be a demonstrated (i.e. statistically observable) reduction of risk either over time (before,

after) or over space (with, without) or over intensity of intervention (more, less). The quality and availability of risk data were also assessed.

(ii) Clarity of causal linkages: There must be reasonable demonstration of the causality of the health risk and of the effectiveness of risk reduction measures taken (i.e. reduction in risk can reasonably be attributed to measures taken).

(iii) Other factors: Additional factors considered include the size of the population at risk, the concentration of decision makers, and clarity of public issues. Desirable case studies would have a reasonably large and identifiable population at risk, a moderate to high concentration of decision making and reasonably clear public issues.

3.2 Long List of Potential Case Studies

With consideration given to the aforementioned criteria, a long list of potential case studies was prepared. Preliminary discussions were held with key informants to determine the prospective feasibility of carrying out an analysis of expenditures for risk reduction. The topics considered and the results of this preliminary assessment are summarized in Table 1-1. The topics selected for further consideration included the following:

- rail crossing improvement
- visual flight rule (VFR) accident reduction
- reduction of trenching accidents in the construction industry
- reduction of occupational exposure to lead
- reduction of accidents in the oil and gas drilling industry
- cervical cancer screening
- immunization (measles)
- tuberculosis testing

The general reasons for excluding topics on Table 1-1 from further consideration are as follows:

- o In many instances it was recognized that there has been a reduction in risk but the available data bases on occurrence of events were insufficient to permit consistent measurement or clear cause-effect isolation of risk reduction. In other words it was not deemed possible to derive a denominator for expenditures-per-unit risk reduction. Examples of topics excluded for this reason include fire resistant children's sleepers, smoke alarms, and protective pharmaceutical packaging. In those cases dependent on Workmen's Compensation Board data, the propensity to report was known to have varied over time as a function of worker knowledge and the public profile of a problem. Thus although effective risk intervention may have taken place the observed result in the claims data was an increasing incidence of claim (e.g. noise related hearing impairment).

- o In other instances the cause-effect health linkages (i.e. between hazard and outcome or between intervention and reduction in outcome) were so poorly understood from a scientific point of view that it has not been possible to derive substantiated dose-response relationships. This situation is particularly prevalent in the area of environmental contaminants where significant effort may go into reduction of perceived risk but where the casualty and nature of that risk is poorly understood (e.g. dioxin captan). In most of these cases there are no population-based data to describe the reduction in health risk and those highly site-specific monitoring studies which are available cannot be legitimately transferred to different populations (i.e. where exposures, confounding factors, and susceptibilities are different). Another problem emerged with respect to the long-lag periods between cause and discernible health effects, particularly resulting from chronic exposure to low-level hazards. In many instances the long-term data are not in place to define and measure health risk.
- o An additional problem relates to multiple cause and effect. For instance there has been a pronounced decline in the normalized frequency of fatal road accidents over the last twenty years. This effect however could be attributed to a wide array of factors including road improvements, vehicle improvements and driver behavior. Isolation of cause and effect might only be possible with massive data bases and complex statistical analysis.

3.3 Final Selection of Case Studies

It was determined that five case studies could be conducted within the budget assigned to this project. It was considered desirable to have studies illustrating:

- (i) types of risk: o accident/injury
o illness/disease
- (ii) locations of hazard: o in the workplace (occupational)
o outside the workplace (environmental)
- (iii) key expenditure decision makers: o government
o industry
o individual

Recognizing the desirability of having a study conducted on individual's decisionmaking additional budget was allowed to permit a fifth case study (children's automobile seat restraint use) which was identified later in the course of the project.

Table 1-2 presents a breakdown of the nine potential case studies in terms of the location of hazard and key decision makers. It is noteworthy that there were no potential case studies identified in the industry/non-workplace category. Industry-related risks outside the workplace typically are associated with environmental contamination or with product safety. The risks associated with environmental contamination are not presently well defined. Data sets associated with product safety typically do not permit empirical isolation of risk reduction achieved with product improvement, particularly when there are multiple and sequential aspects of product improvement.

The following case studies were selected on the overall basis of data availability, clarity of cause and effect and potential for industry participation:

- cervical cancer screening
- rail crossing signal improvement
- oil and gas drilling accident reduction
- reduction of occupational exposure to lead
- purchase and use of children's automotive seat restraints

Table 1-1: Long List of Potential Case Studies

Topic Area	Preliminary Feasibility Assessment	Selected for Further Study?
A. <u>Food Safety</u> - reduction of food poisoning and toxic contaminant risk by: - o improvement of processing methods - pasteurization, canning methods - o screening, testing and monitoring of food additives and chemical contaminants: - saccharine - nitrites - fungal toxins (vomitolxin, aphlotoxin) - agricultural chemicals (e.g. captan fungicide used on apples)	- o mortality and morbidity data old and difficult to access - o screening and testing of new products is designed to preempt risk; difficult to measure risk reduction - o scientific evidence of cause/effect and dose/response relationships is generally unclear - o retroactive banning of harmful constituents may reduce risk but definition of cost is unclear	NO NO
B. <u>Drug Safety</u> - reduction of overdose, poisoning, side effects and associated illness risk by: - o improvements in packaging: - children's aspirin - o screening and testing: - aspirin, Reyes syndrome - estrogen - thalidomide	- o drug poisoning data poor; source of poisoning often unknown or unrecorded - o screening and testing of new products is designed to preempt risk; difficult to measure risk reduction - o retroactive banning of harmful drugs reduces risk but definition of cost is unclear	NO NO

Table 1-1 (Continued): Long List of Potential Case Studies

Topic Area	Preliminary Feasibility Assessment	Selected for Further Study?
C. Consumer Product Safety - reduction of injury and mortality risk by improved product design and/or materials		
o child product safety		
- fire resistant sleepers	o legislation in place, cost of compliance reasonably clear but statistical evidence of risk reduction poor	NO
- lead paint - banning on children's furniture	o same as above	NO
- cribs - improved design	o same as above	NO
o recreational safety		
- hockey helmets	o accident data base poor	NO
- eye protection - racquet sports	o same as above	NO
- swimming pools - covers, fences, etc.	o same as above	NO
- ski equipment	o same as above	NO
o other		
- christmas lights (fire risk)	o statistical evidence of risk reduction poor	NO
- electrical appliances (electrocution risk)	o statistical evidence of risk reduction poor	NO
- sanitary napkins (toxic shock syndrome)	o cause and effect of hazard under study and debate	NO
- chain saws	o statistical evidence of risk reduction poor	NO
- domestic herbicides and pesticides	o cause and effect of hazard under study and debate	NO

Table 1-1 (Continued): Long List of Potential Case Studies

Topic Area	Preliminary Feasibility Assessment	Selected for Further Study?
D. <u>Environmental Contaminants/Pollution</u> - reduction of public health risks attributable to contaminants of air, water and soil such as: - o mercury - chlor - alkali industry - o lead - o asbestos - o dioxin - o PCB's - o captan	- o statistical evidence of risk reduction poor - o same as above - o cost of risk reduction clear but statistical evidence of risk reduction is poor - o effects and dose/response relationships are poorly understood - o same as above - o same as above	- NO - NO - NO - NO - NO - NO
E. <u>Transportation Safety</u> - reduction of public injury and mortality risk in transportation sectors as follows: - o rail - level crossing improvement to reduce vehicle - train collisions - hazardous goods transport - o air - reduction of visual flight rule VFR accidents - enhanced avionics - o automobile - seat belt legislation	- o good data on cost and accident risk in place - o statistical evidence of risk reduction poor - o good data on cost and accident risk in place - o theoretical studies done but statistical evidence of risk reduction is poor - o demonstrated risk reduction but basically a behavioural not cost issue	- YES - NO - YES - NO - NO

Table 1-1 (Continued): Long List of Potential Case Studies

Topic Area	Preliminary Feasibility Assessment	Selected for Further Study?
E. (Continued)		
- air bags	o costs clear but no statistical evidence of risk reduction	NO
- child restraint devices	o costs clear, accident statistics indicate risk reduction	YES
- road design	o difficult to isolate multiple cause and effect	NO
- automobile design	o difficult to isolate multiple cause and effect	NO
o marine		
- laker explosions prevention (grain dust)	o statistical evidence of risk reduction poor	NO
- search and rescue	o statistical evidence of risk reduction poor	NO
F. Fire Safety - reduction of injury and mortality risk attributable to residential and commercial fires through such measures as:		
o building and building product materials and design improvement	o costs clear, difficult to isolate multiple cause and effect in Canadian data base	NO
o smoke alarms	o cost clear, difficult to isolate effectiveness in Canadian data base	NO

Table 1-1 (Continued): Long List of Potential Case Studies

Topic Area	Preliminary Feasibility Assessment	Selected for Further Study?
G. Occupational Safety - reduction of injury and mortality risk attributable to such hazards as:		
o mining industry - rock bursts, rollovers	o evidence of risk reduction in place, industry not willing to participate	NO
o construction industry - trenching	o clear evidence of intervention and reduced accidents	YES
o oil and gas industry - rig accidents	o evidence of risk reduction in place, reasonable prospects of industry participation	YES
H. Occupational Health - reduction of health risks attributable to such hazards as:		
o benzene	o small population at risk, risk reduction difficult to specify	NO
o vinyl chloride	o same as above	NO
o noise	o evidence of risk reduction confounded by increased reporting	NO
o silica	o same as above	NO
o asbestos	o same as above	NO
o lead	o blood lead concentration data in place	YES
o cook oven/foundry gases	o small population at risk, risk reduction difficult to specify	NO

Table 1-1 (Continued): Long List of Potential Case Studies

Topic Area	Preliminary Feasibility Assessment	Selected for Further Study?
I. Communicable and Non-communicable Diseases - reduction of the incidence and severity of disease by such measures as:		
o Immunization	o data somewhat old but risk reduction well documented, cost data from provinces	YES
o health screening:		
- cervical cancer	o risk reduction well documented, cost data from provinces	YES
- tuberculosis testing	o same as above	YES
o open heart surgery	o difficult to isolate effectiveness since multiple forms of treatment often applied	NO

Table 1-2: Short List of Potential Case Studies by Location of Hazard and Key Decision Makers

Key Expenditure Decision Makers	Workplace	Non-workplace
Government		- o rail crossing improvement - o VFR accident reduction - o cervical cancer screening - o immunization - o tuberculosis testing
Industry	- o trenching accidents - o lead exposure - o drilling accidents	
Individual		o children's seat restraints

PART B - CASE STUDIES FOR

Cervical Cancer Screening

Rail Crossing Signal Improvement

Oil and Gas Drilling Accident Reduction

Reduction of Occupational Exposure to Lead

Purchase and Use of Children's Automotive Seat Restraints

CASE STUDY NUMBER 1

CERVICAL CANCER SCREENING

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1. CERVICAL CANCER SCREENING

1.1 Introduction

This case study examines the implementation of cytological screening programs in British Columbia for the purposes of preventing mortality from cancer of the cervix. There is substantial accumulating evidence that properly managed use of the commonly known "Pap test" can provide accurate early diagnosis of pre-cancerous and cancerous lesions of the cervix, thus allowing for therapeutic intervention and reduction of mortality risk. The study focuses on the screening program implemented in the province of British Columbia. Because of the early initiation of screening in that province and the centralization of laboratory facilities, reliable data relating to efficacy and cost were readily available.

1.1.1 Background and History: The British Columbia Experience

Diagnostic cytology for cancer of the cervix was introduced in 1943 in a monograph by Papanicolaou and Traut on diagnosis of uterine cancer by the vaginal smear. It took several years for the medical profession to appreciate the value of the technique and several more years to convince the public that the Pap test could detect cancer of the cervix in the earliest stage of development. As the Pap test became a routine examination by many doctors treating women, screening programs for the detection of cancer of the cervix developed (Popkin 1976).

The first such program was established in British Columbia with the provision of a provincially organized cervical cytology service based in one large central laboratory. The program began in 1949 as a diagnostic laboratory and gradually expanded its activities to include population screening in the 1950s. In the 1960s, with the assistance of the Canadian Cancer Society (CCS) and the opportunity provided by large numbers of women requesting prescriptions for oral contraceptives, the program became province wide (Fidler *et al* 1962). This program quickly became the flagship against which the achievements of other programs in Canada and elsewhere tend to be measured. Table 1-1 shows that British Columbia has consistently led other provinces in the extensiveness of its program. Further information on the history of screening in Canada is provided in Appendix 1.1.

1.1.2 Nature of the Disease

Cancer of the cervix ranks amongst the top ten sites of cancer among Canadian women in terms of both incidence and mortality. Table 1-2 presents data for British Columbia (1982) demonstrating that cancer of the cervix is much less frequently encountered than cancer of the breast, lungs and colon. Moreover, the mortality rate due to cervical cancer is significantly below rates for these and several other sites. The relatively high incidence of cervical cancer in younger women has however led to intensive efforts in early diagnosis, prevention and treatment.

Table 1-1: Extent of Cervical Screening Performed in Canada in 1971, 1975, 1977 and 1979

PROVINCE	1971	NO. OF SCREENS PER 100 WOMEN AGED 20 YEARS OR MORE*		1979
		1975	1977	
British Columbia	55	61	55	57
Alberta	40	48	47	48
Saskatchewan	41	47	48	47
Manitoba	46	51	50	48
Ontario	39	45	44	44
Quebec	29	42	43	45
New Brunswick	22	41	37	40
Nova Scotia	37	35	45	46
Prince Edward Island	28	37	41	44
Newfoundland	36	43	42	44
Canada	38	45	45	46

* Not to be equated with the number of women screened. Historically, annual 'pap smears' were recommended for women of 20 years and older, the basis of which was strictly arbitrary.

Source: Walton et al (1982). Canadian Medical Association Journal, Oct, 1982, Volume 127. Reprinted with permission.

Table 1-2: Incidence and Mortality Rates by Site¹
British Columbia Women 1982

INCIDENCE	RATES PER 100,000 POPULATION		MORTALITY
1. Other Skin	76.8	1. Breast	24.8
2. Breast	70.7	2. Trachea, Bronchus, Lung	18.3
3. Trachea, Bronchus, Lung	22.8	3. Colon	10.5
4. Colon	21.8	4. Ovary	8.6
5. Uterus	15.8	5. Pancreas	5.9
7. Rectum	11.8	6. Leukemia	4.6
6. Ovary	12.4	7. Stomach	4.2
9. Cervix	8.3	8. Cervix	3.5
8. Non-Hodgkin's Lymphoma	8.5	9. Non-Hodgkins's Lymphoma	3.4
10. Melanoma-Skin	8.1	10. Uterus	3.0

Source: Annual Report 1983/84
Cancer Control Agency of British Columbia

Notes: 1. Age standardized rates. Nominal incidence and mortality rates are adjusted on the basis of a fixed population age distribution which is agreed upon by convention.

The natural history and causative factors linked to cervical cancer are not completely understood. Comparisons of incidence rates amongst countries in the 1960s indicated a range of incidence with a high of 180 per 100,000 population in Columbia to a low of 12 in Israel. Comparison of mortality rates indicated a four to five-fold variation amongst countries and a two to three-fold variation amongst provinces in the later 1960s and early 1970s. (Walton et al 1976). The causative factors underlying this variation have not been determined but a large number of epidemiological studies suggest that early onset of sexual activity in the female, particularly with multiple male partners, is associated with incidence of and mortality from cervical cancer.

Cervical cancer is generally considered to be a progressive degenerative disease. It is this aspect of the disease combined with the availability of a reliable testing procedure and successful treatment techniques that have led to the introduction and acceptance of screening programs. Figure 1-1 demonstrates the stages of disease progression as defined by cytological observation. Case history analyses have provided the following insights into the natural history of the disease:

- o There is not a 100% progression from one stage to the next. In general the rate of progression increases as one moves down the sequence of stages (e.g. 80% to 90% of in situ cancers would progress to clinical cases without intervention, D. Boyes pers. comm.).
- o There is evidence that 30% to 40% of dysplastic conditions regress and that a certain proportion of in situ conditions may also regress (as noted by the return lines in Figure 1-1).
- o There is also evidence that a certain low proportion of dysplastic conditions progress rapidly to a micro-invasive in situ condition, thus making cytological diagnosis and effective treatment more difficult.

Current research into the causative factors underlying cervical cancer are focused on the role of the Human Papilloma Virus (HPV 16, 18) and other viruses as associated agents and on the role of diet, particularly vitamin intake, in determining propensity for malignancy.

1.1.3 Risk Reduction by Screening and Treatment

Reduction in the incidence of late stage cervical cancer and resultant mortality can result from a combination of early cytological diagnosis and effective follow-up treatment. The following sections outline the cytologic laboratory and treatment modalities implemented in British Columbia.

(a) Cytological Screening

Screening is the deliberate examination of substantial segments of the population in search for disease at its earliest stages, in the hope that disability and mortality from the disease will be reduced. The screening tests used must sort out apparently well persons who probably have the disease from those who probably do not. A screening test is not intended to be fully

Figure 1-1: Simplified Natural History of Cervical Cancer



Source: Walton et al 1976
Boyes, 1981

diagnostic in that persons with positive or suspicious findings must be studied further for a final diagnosis. Figure 1-2 presents the typical sequence of events following normal and abnormal Pap smears.

For screening to be advantageous, it is desirable that 1) the disease has a serious consequence; 2) the treatment is better on screen-detected disease than on symptom-detected disease and; 3) there should be a high prevalence of detectable preclinical evidence of the disease. Cytological screening programs for cervical cancer meet these three prerequisites and, for the most part, the following evaluation criteria are often used for assessing screening programs:

- (i) Sensitivity - The ability of the test to give a positive finding when the person has the disease under study.
- (ii) Specificity - The ability of the test to give a negative finding when the person treated is free from the disease under study.
- (iii) Simplicity - The test should be easy to perform.
- (iv) Acceptability - The test should be acceptable to the subjects.
- (v) Accuracy - The test should give a true measurement of the attribute under investigation.
- (vi) Precision - The results should give consistent results in repeated trials.
- (vii) Cost - The expense should be reasonable in relation to the benefits resulting from the early detection of disease.

There has been a screening program for cervical cancer operating in British Columbia since 1949. Cytologic and histologic analysis has been conducted by one central laboratory operated by the Cancer Control Agency of British Columbia (CCABC). Smears are obtained by mail from the offices of general practitioners, gynecologists, family planning clinics, venereal disease clinics and outpatient departments. The number of cases screened annually has risen gradually from 5,500 in 1953 to approximately 500,000 in 1985. Figure 1-3 shows the increase in number of women screened (in 2-year intervals) since the early stages of the program. Increases in the late 1950s are attributed to promotional efforts of the Canadian Cancer Society and subsequent increases in the 1960s attributed to the recommendation that women on birth control pills or IUDs be screened annually. The central laboratory also recommends standard diagnostic criteria and treatment policies. The CCABC reports that the first 25 years of operation (to 1974) were intended to prove the worth of the program and that after 1974 the emphasis was shifted from research to patient convenience and safety.

Figure 1-2: Sequence of Events Following Normal and Abnormal Pap Smears

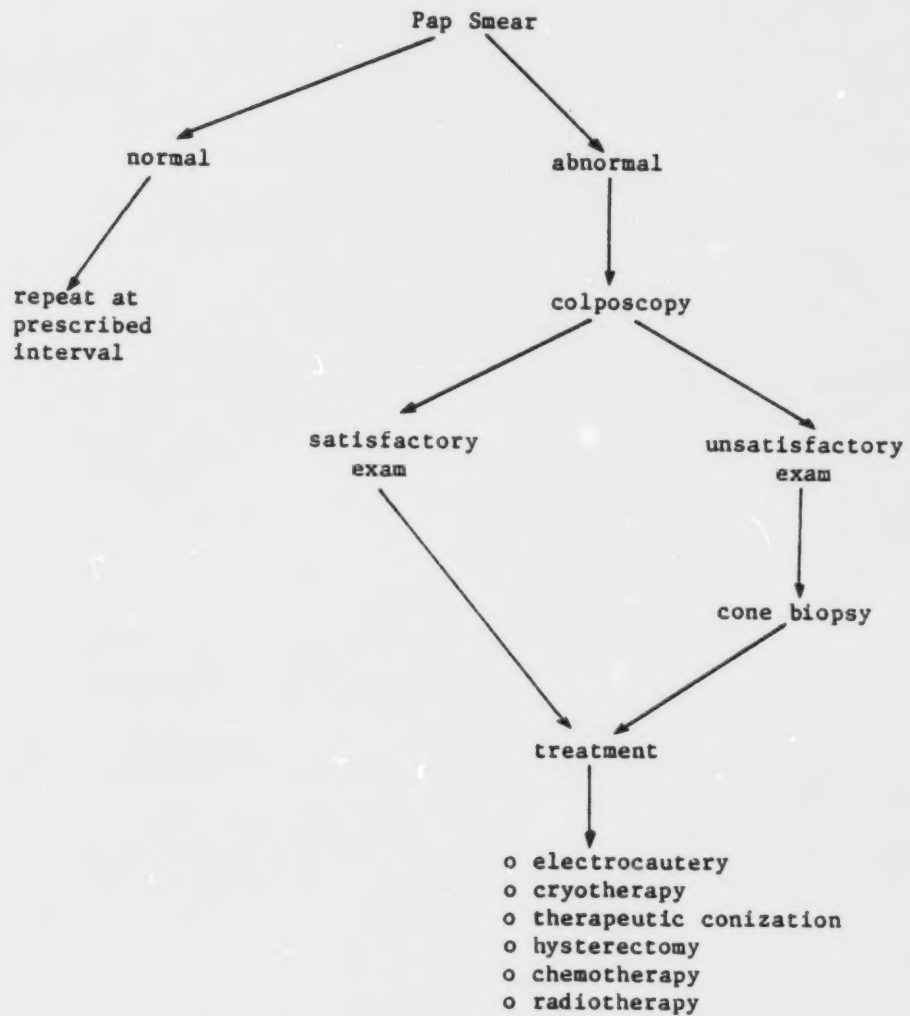
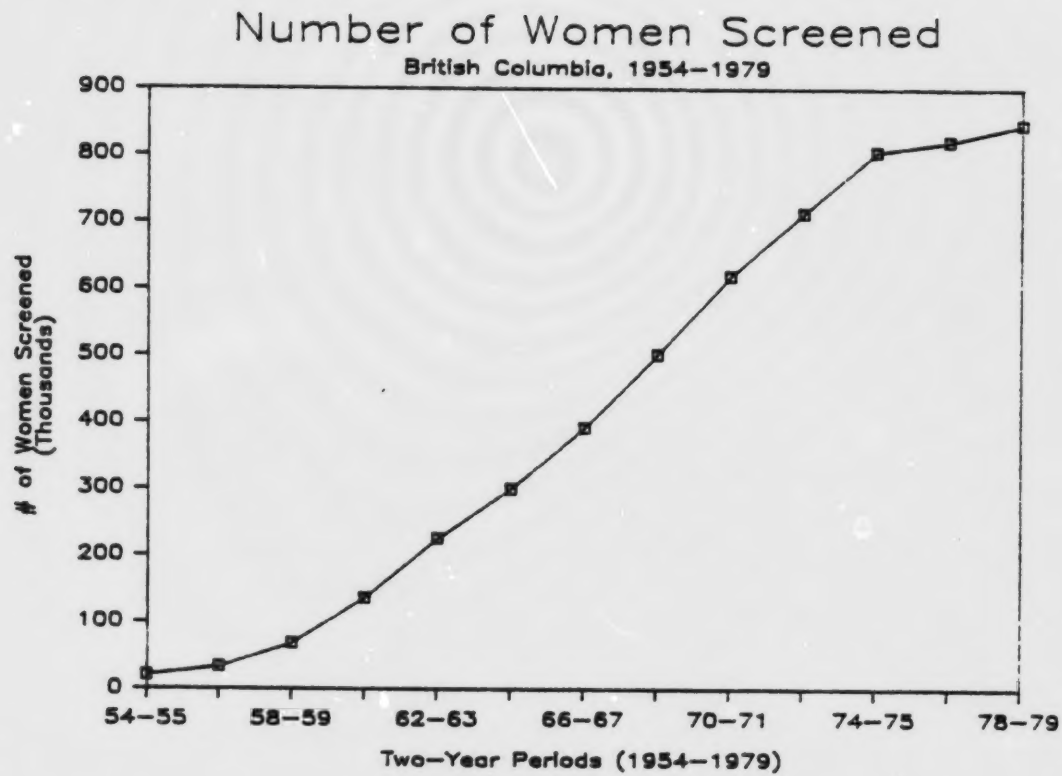


Figure 1-3: Number of Women Screened, British Columbia 1954-1979



(b) Treatment

Prior to 1974, the standard methods of treating the various cytologically defined stages of cancer were as follows:

- o in situ carcinoma : cone biopsy
- o in situ with microinvasion : recone, hysterectomy
- o occult invasive carcinoma : radical hysterectomy, radiation

Treatment of in situ cancer has typically been about 93% to 99% successful whereas the case fatality for occult cancer is about 50% with existing treatments. In the early 1970s, the decision was made to investigate abnormal Pap smears using colposcopy, the visual examination of the cervix using a low-power microscopic instrument. This technique is used to confirm a cytological report and can be combined with electrocautery or cryotherapy for treatment of non-invasive sites. There are now 18 colposcopy clinics throughout the province which are run by gynecologists trained at the CCABC. This form of follow-up and treatment is less intrusive and more convenient for patients (i.e. as compared to cone biopsies and hysterectomies).

1.1.4 Objectives and Scope

The objectives of this case study are to:

- (i) document the effect that cytological screening has had on the incidence of and mortality from cervical cancer;
- (ii) estimate the total expenditures associated with implementation of cervical cancer screening in a given jurisdiction;
- (iii) derive an estimate of the expenditure per unit of risk reduction; and
- (iv) describe the roles, responsibilities and rationales of medical institutions, medical professional associations, non-profit agencies and government departments with regard to decision-making on the implementation and continued operation of cervical cancer screening.

The case study is limited to:

- (i) cervical cancer only, excluding other uterine sites;
- (ii) measurement of risk reduction and expenditures in the province of British Columbia. Although data from other areas is examined in the course of this study, expenditures are for the province of British Columbia only.
- (iii) the period of time for which incidence and mortality data are available for the province of British Columbia (1954 to 1985).

1.2 Methodology

1.2.1 Definition of Risk

For the purposes of this case study risk is defined as the annual frequency of death due to cervical cancer per 100,000 females over 20 years of age. Risk is therefore defined as an average population-based measure of the probability of dying in any given year.

At the individual level the probability of death due to cervical cancer can further be defined as a function of risk factors such as:

- o age
- o previous health history
- o age at onset of sexual activity
- o number of sexual activity partners

Other risk factors currently being explored include diet and viral infection (herpes Type 2, human papilloma virus).

1.2.2 Documentation of Risk Reduction

The main methods used to document risk reduction were:

(i) a review of the general literature relating to the effectiveness of cytological screening in other Canadian provinces and worldwide. This review has conducted to establish a broad perspective on the efficacy of screening;

(ii) analysis of historical information maintained and provided by the Cancer Control Agency of B.C., including data on cases screened, incidence and mortality and related analyses.

Risk reduction was measured as the difference in mortality rate between an initial point in the program (1955) and a later point in the program (1979) where the program may likely be achieving its maximum benefit. The data are fully discussed in Section 1.3.1.

1.2.3 Collection of Expenditure Data

Data on expenditures related to the cervical cancer screening program in British Columbia were obtained from the Cancer Control Agency of British Columbia. Funding for the program is provided by the British Columbia Ministry of Health through the B.C. Hospital Programs budgeting process with a separate budget identified for the screening laboratory.

The expenditure data obtained pertain to the cytological laboratory costs only and do not include:

- o treatment costs, including the sessional costs of colposcopy clinics.

- o costs associated with the medical practitioner's time required to take a sample or interpret results.
- o indirect costs borne by the patient in attending an appointment for taking of a sample or for treatment. Such indirect costs typically include babysitting, transportation, parking and foregone earnings.

The estimated costs were provided in terms of cost per smear analyzed as of 1955 and 1985-86 in current-year dollars (i.e. then years, as-spent). The costs include laboratory staff, supplies, mail, capitalized equipment and computing facilities costs but exclude space, janitorial, light and power costs which are included as part of the general overhead of the CCABC.

Total costs are calculated by multiplying the number of cases screened times the unit cost per screening. Unit costs per screen (i.e. pap smear) for years between 1955 and 1985 have been interpolated as follows:

	cost per smear	
	current year \$	constant year \$ (1985 \$)
1955*	1.50	6.70
1956 to 1959	1.50	6.70
1960 to 1964	1.60	6.35
1965 to 1969	1.80	6.30
1970 to 1974	2.20	6.30
1975 to 1979	3.35	6.30
1980 to 1984	4.75	5.50
1985*	5.50	5.50

*actual estimates provided by CCABC.

1. Interpolation of unit costs in intervening years (1956 to 1984) has been based on the mid-year Canada Consumer Price Index to 1979; the 1980 to 1984 figure is approximate, based on a less than inflationary increase.
2. Constant dollar unit costs have been based on the Canada Consumer Price Index. All values have been rounded to the nearest \$0.05.

With respect to treatment costs it is clear that the early detection of cervical cancer and subsequent treatment by inexpensive non-intrusive methods rather than expensive intrusive surgical, radiation and drug treatments implies a cost exchange. The exchange is between a lesser number of high unit cost treatments and a greater number of low unit cost treatments. This exchange is generally not evaluated on the basis of cost but is an outcome of overall considerations of patient convenience, safety and case fatality expectation. We have not attempted to assess the effect of screening on net treatment costs inclusive of this exchange. From a societal point of view, however, it is clear that a reallocation of treatment expenditures would occur as a result of the screening program. Cost-effectiveness analysis of alternative screening/treatment strategies would therefore have to include consideration of comparative unit treatment costs.

It should also be noted that maintaining a lowered mortality rate implies an ongoing screening effort (i.e. repeat tests and recruitment of young women to the program). Assuming a fixed female population size in the 20 years+ group this implies an expenditure of approximately \$2.5 million per annum (1985 \$) at existing screening frequencies (i.e. 500,000 screens at approximately \$5 per screen). In the calculations that follow this assumption was not made.

1.3 Results

1.3.1 Evidence of Risk Reduction from the British Columbia Screening Program

Table 1-3 summarizes key information for the B.C. screening program over the 1954 to 1979 period. Figure 1-4 demonstrates that screening activity has reached a point where it is reported that about 60% of the female population over 20 years of age is screened every year and that about 85% of that population has been screened at least once. It is suggested that a certain small proportion of the population may never be reachable by the program given migration in and out of the province.

As the numbers of women screened have increased, so have the numbers of cases of in situ carcinoma discovered through screening increased (Figure 1-5). Given the high degree of success in treating these pre-clinical cases, the simple expectation would be that the incidence of clinical cases and resultant mortality would vary inversely in a lagged fashion with the incidence of detected and treated in situ carcinoma (all other factors held constant).

Figures 1-6 and 1-7 present the trends in incidence of clinical disease and mortality over the period in which the screening program has been active. Unfortunately, data are not available for any part of the pre-program period. It is apparent that both incidence of clinical disease and mortality have declined significantly over the 1955 to 1985 period.

In principle a reduction in incidence of clinical cervical carcinoma can result from:

- i) a reduction in the natural prevalence of precursor stages (i.e. carcinoma in situ).
- ii) intervention in the progression of the precursor stage (i.e. through screening and treatment).

In the absence of independent randomized sampling of the screened and unscreened populations, it is not possible to differentiate the possible influences of these two factors.

The results of the screening program as presented in Figure 1-8 are however suggestive of the following possibilities:

- o Incidence rates of in situ carcinoma within the screened population show a general decline over the 1955 to 1972 period. To the extent that the screened population accurately reflects the total population this

Table 1-3: Basic Data for Cervical Cancer Screening in B.C. 1954 - 1979

YEAR	NUMBER OF WOMEN SCREENED (1)	AVERAGE POPULATION ('000's) (2)	NO. OF WOMEN SCREENED/ AVERAGE POP'N (3)	NO. OF CASES OF IN SITU CARCINOMA (4)	INCIDENCE RATE OF ISC IN SCREENED POP'N (5)	INCIDENCE RATE OF ISC IN AVERAGE POP'N (6)	INCIDENCE RATE OF CLINICAL INVASIVE CANCER (7)	MORTALITY RATE (REFINED) (8)
1954-55	20,555	422.90	0.05	89	433	21	28.4	-
1956-57	33,825	448.90	0.08	171	506	38	26.6	-
1958-59	68,718	475.85	0.14	283	412	59	23.2	11.0
1960-61	136,548	491.20	0.28	446	327	91	21.5	10.1
1962-63	225,468	508.00	0.44	638	283	126	17.3	12.0
1964-65	300,256	535.00	0.56	961	320	180	15.5	9.2
1966-67	391,800	579.45	0.68	1290	329	223	14.0	7.1
1968-69	502,270	626.80	0.80	1364	272	218	13.5	8.0
1970-71	619,843	675.80	0.92	1490	240	220	11.5	7.5
1972-73	713,748	727.25	0.98	1582	222	218	9.4	5.8
1974-75	805,794	790.40	1.02	2093	260	265	8.7	5.0
1976-77	822,132	835.35	0.98	2782	338	333	8.0	4.3
1978-79	847,465	880.30	0.96	3489	412	396	7.5	5.3

- (1) Number of individual women screened over two-year intervals (screened population).
(2) Average population of women 20 years or older over two-year intervals.
(3) Hereafter referred to as the screening index.
(4) Excluding small numbers of in situ with micro-invasion.
(5)(6) ISC = In Situ Carcinoma, two-year average rates per 100,000 females over 20 years of age.
(7)(8) Two-year average rate per 100,000 females over 20 years of age.

Source: Boyes (1985)

Figure 1-4: Cervical Cancer Screening Index, B.C.

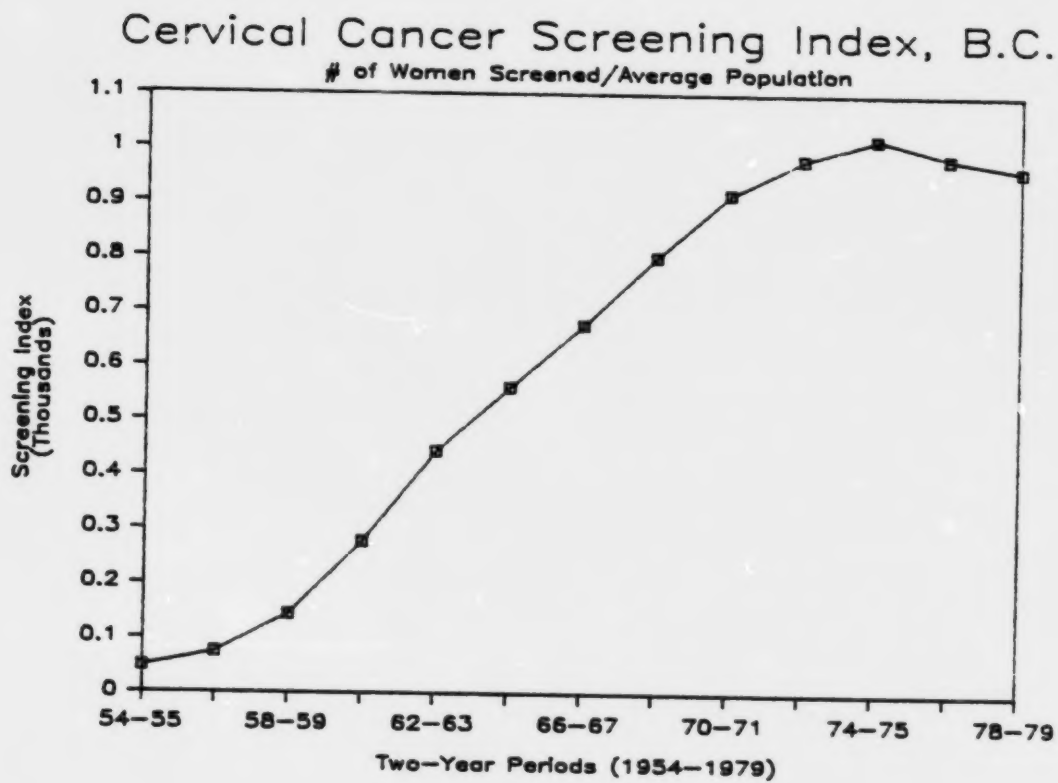


Figure 1-5: Number of Cases of In Situ Carcinoma, B.C., 1954-1979

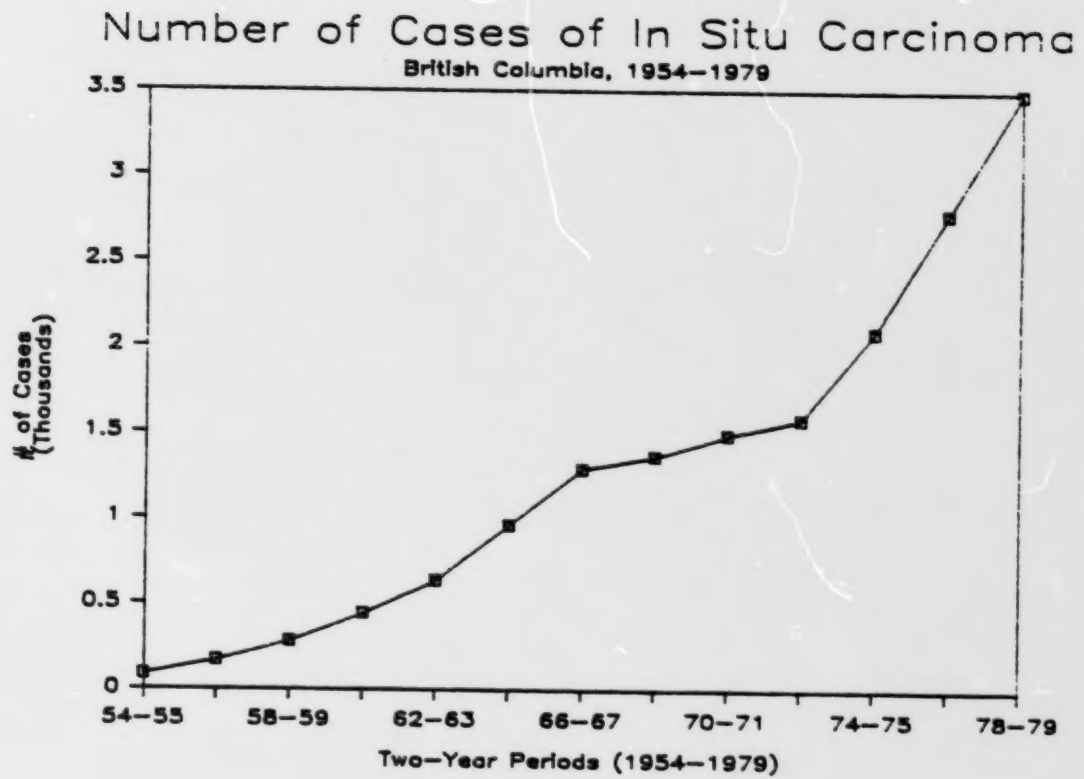


Figure 1-6:

Incidence of Clinical Squamous Carcinoma of the Cervix
in Females Over 20 Years of Age in British Columbia 1955 - 1984

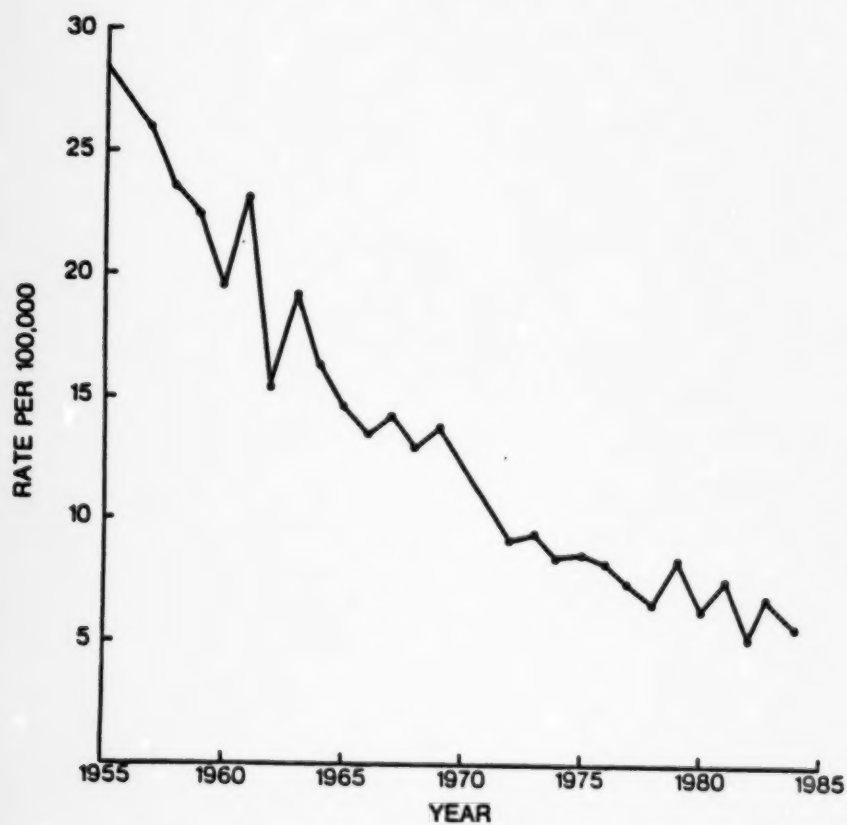


Figure 1-7:
Mortality from Squamous Carcinoma of the Cervix
in Females Over 20 Years of Age in British Columbia 1958 - 1984

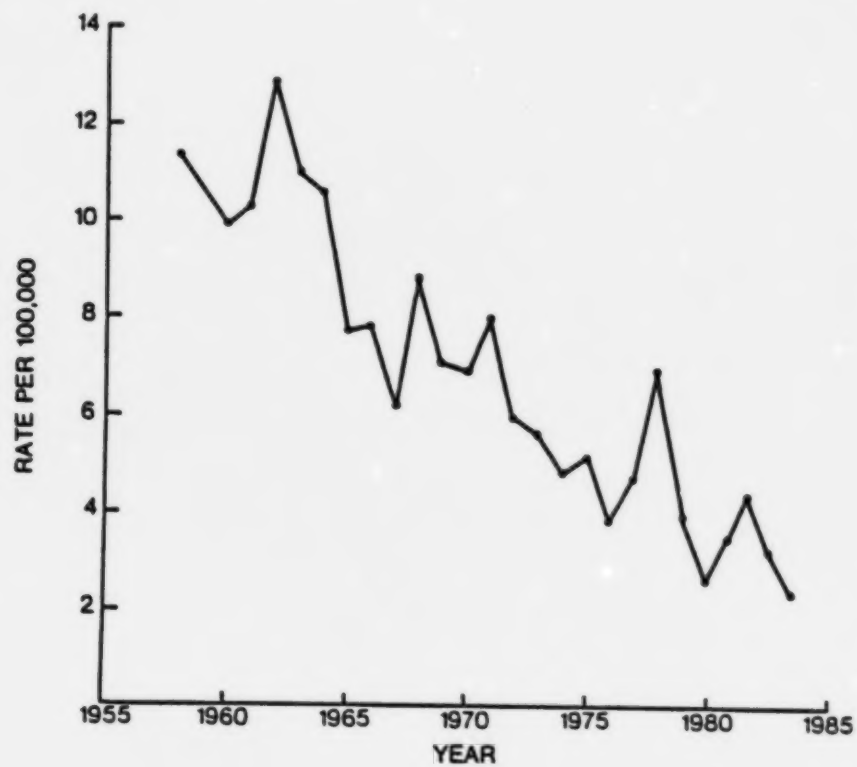
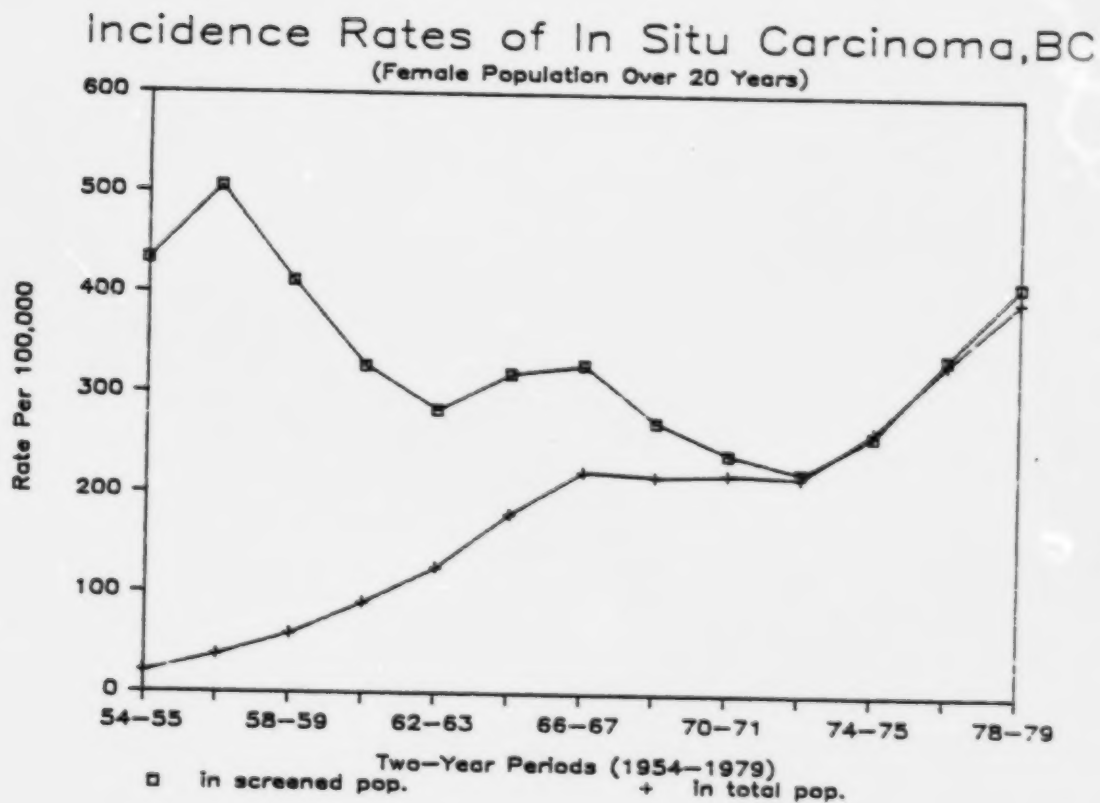


Figure 1-8: Incidence Rates of In Situ Carcinoma, B.C., 1954-1979
(Female Population Over 20 Years)



phenomenon alone would likely contribute to some lagged reduction in the incidence of clinical disease. The decline may however be simply due to changes in the composition of the population being screened (e.g. age, sexual activity history) relative to the total population.

- o Incidence rates of cytologically detected in situ carcinoma within the total population increase in conjunction with the extent of screening. Thus, regardless of any reduction in natural prevalence, the effect of this increase would be to divert in situ cases into successful treatment.

- o It is particularly notable that the rise in incidence of in situ carcinoma observed at high screening levels from 1972-73 onwards is not manifested in an increased incidence of clinical cancer in subsequent years. The conclusion which may be drawn is that screening was successful in pre-empting the progression of a high proportion of in situ cases. Analysis of incidence at age shows elevated levels of in situ incidence amongst younger age groups. This phenomenon has been theorized to be associated with an increase in promiscuous sexual activity at that time.

Interpretation of the reduction in mortality rate observed in Figure 1-7 requires consideration of the following points:

- o A change in the mortality rate can result from changes in clinical case treatment methods (i.e. case fatality expectation) as well as from changes in the incidence of clinical cases. The case fatality expectation for clinical cases has not, however changed significantly over the period of study.

- o The observed reduction in mortality could be in part attributable to an independent and concurrent decline in the natural prevalence of the disease (i.e. related to such factors as diet, hygiene, general health care, sexual practices).

Although there is no independent corroboration of such a decline occurring in B.C., there is evidence in the historical national data set (See "Cancer Patterns in Canada 1931 - 1974", Health and Welfare Canada, Health Protection Branch) suggestive of an overall national decline in mortality from cancer of the cervix commencing in 1950-52, prior to the implementation of provincial screening programs.

For the purposes of this case study, risk reduction is defined as the reduction in the rate of mortality from cervical cancer observed in B.C. between 1958 and 1980. For the purposes of estimating this reduction, the following values are used:

1958-59 average rate = 11.0 per 100,000 females 20+ years of age
1979-80 average rate = 3.0 per 100,000 females 20+ years of age
reduction = 8.0 per 100,000 females 20+ years of age

In electing to use this value, the following points should be borne in mind.

1) This amount of reduction represents the maximum that might be attributed to screening. To the extent that factors independent of screening have led to concurrent reduction in risk, the amount attributed to screening would be smaller.

ii) The temporal frame of reference for estimation of risk reduction is a start and end point consistent with the initiation and popularization of the program. Given recent rises in incidence of in situ cancer in younger women (1975-1980), it is possible that a projected hypothetical mortality rate in the absence of the program could exceed 11.0 per 100,000 women. The calculation of such a rate is considered to be highly conjectural, particularly given recent variability in the incidence rate and basic questions regarding disease progression.

It is notable that by applying a uniform hypothetical mortality rate of 11.0 over the 1958 to 1979 period, and by subtracting actual deaths over this period, it can be estimated that approximately 620 lives may have been saved over the period (Table 1-4). A more accurate estimate of lives saved would require a detailed analysis of the expected incidence of clinical invasive cases in the absence of the screening program as well as a projection of case fatality.

1.3.2 Expenditures on Risk Reduction

Table 1-5 presents a summary of expenditures on cytological screening for cervical cancer in British Columbia over the 1958 to 1979 period. This period has been selected to be consistent with the reduction in mortality observed (Section 1.3.1(c)).

Total expenditures in current dollars are approximately \$13.1 million over this period. Under assumptions of constant dollars (i.e. were all the screening to have been done in 1985) the equivalent cost is estimated to be approximately \$34.3 million.

1.3.3 Expenditures per Unit Risk Reduction

(a) Aggregate Expenditures

Using the expenditure data noted above and a reduction in mortality of 8.0 per 100,000 females 20+ years of age, the following estimates of expenditure per unit mortality risk reduction are derived:

Table 1-4: Estimated Number of Lives Saved by Screening for Cervical Cancer

YEAR	POPULATION (IN 000's) OVER AGE 20	ACTUAL DEATHS*	EXPECTED DEATHS**	ESTIMATED LIVES SAVED
1958	473.0	54	52	-2
1959	478.7	51	53	2
1960	486.4	48	54	6
1961	496.0	51	55	4
1962	503.0	54	55	1
1963	513.0	57	56	-1
1964	526.8	56	58	2
1965	543.2	42	60	18
1966	566.5	44	62	18
1967	592.4	38	65	27
1968	615.4	54	68	14
1969	638.2	45	70	25
1970	664.4	46	73	27
1971	687.2	55	76	21
1972	713.1	43	78	35
1973	741.4	42	82	40
1974	775.3	37	85	48
1975	805.5	42	89	47
1976	826.1	31	91	60
1977	844.6	40	93	53
1978	868.4	61	96	35
1979	892.2	35	98	63
1980	926.1	23	102	79
TOTAL		1,049	1,669	620

* refined estimate

** based on 11 deaths per 100,000

Source: Boyes (1985) for population and refined estimate of actual deaths.

Note: This method provides a minimal estimate of lives saved due to the 4-5 year lag in death following incidence of invasive cancer.

Table 1-5: Expenditures on Screening for Cervical Cancer in B.C. 1958 to 1979

YEAR	NUMBER OF WOMEN SCREENED ¹	COST PER SCREENING		TOTAL EXPENDITURES	
		CURRENT \$	CONSTANT (1985) \$	CURRENT \$	CONSTANT (1985) \$
1958-59	68,718	1.50	6.70	103,077	460,411
1960-61	136,548	1.60	6.35	218,477	867,080
1962-63	225,468	1.60	6.35	360,749	1,431,722
1964-65	300,256	1.60	6.35	480,410	1,906,626
1966-67	391,800	1.80	6.30	705,240	2,468,340
1968-69	502,270	1.80	6.30	904,086	3,164,301
1970-71	619,843	2.20	6.30	1,363,655	3,905,011
1972-73	713,748	2.20	6.30	1,570,246	4,496,612
1974-75	805,794	2.20	6.30	1,772,747	5,076,502
1976-77	822,132	3.35	6.30	2,754,142	5,179,432
1978-79	847,465	3.35	6.30	2,839,008	5,339,030
TOTAL				13,071,834	34,295,064

Note: 1. The number of women screened is approximately equal to the number of cytological samples tested. A very small proportion of women are screened more than once per two years.

- (i) current dollars (then years, as spent)

$\$13,071,834 / 8.0 = \$1,633,980$ per unit reduction in mortality rate from cervical cancer.

- (ii) constant dollars (1985 \$)

$\$34,295,064 / 8.0 = \$4,286,883$ (1985 \$) per unit reduction in mortality rate from cervical cancer.

(b) Expenditures per Life Saved

Assuming a saving of 620 lives over the study period (see Section 1.3.1(c)), the historically derived screening expenditures per life saved are \$21,084 (current \$) and \$55,315 (1985 \$). These costs are exclusive of treatment costs.

1.4 Discussion

1.4.1 Reliability of Estimates

The estimated expenditures per unit risk reduction as derived in this study are sensitive to the following factors:

(a) The temporal framework for measuring reduced risk. In this study we adopted the approach of measuring reduction over a period of time defined by a beginning and end point rather than at one point in time under assumptions of with and without screening. The latter approach requires a projection of disease progression to fatality, a calculation which we elected not to make on the grounds of technical complexity. The results under such an approach may very well have resulted in a higher estimate of risk reduction given the elevated incidence of in situ cancer observed in young age groups in the 1970's.

(b) The types of expenditures included. Some facilities, space and overhead costs were not included in this study; their inclusion would likely increase costs by a relatively constant factor (likely 1.1 to 1.2). In addition, net treatment costs are not accounted for in this study. Although net changes in overall treatment costs were not cited as a factor considered in implementing the screening program, from a societal point of view such net changes should be considered in evaluating the true cost of saving and extending lives. Without further analysis it is not possible to determine whether the net change in treatment cost has been positive, negative, or neutral.

1.4.2 Roles, Responsibilities and Rationales for Implementation of the B.C. Screening Program

Responsibility for implementation, management and modification of cervical cancer screening programs in Canada is vested in a number of players. Funding of such programs is solely within provincial jurisdiction. The role of the

federal government is in supporting research, setting national standards of nomenclature and technique, maintaining national data and in providing a forum for consensus.

Decisions surrounding participation in a screening program and frequency of screening are made by doctors (and other health professionals) and women. In the view of members of the 1982 Cervical Screening Task Force (Walton et al 1982) the "primary responsibility to enter and continue in a cervical screening program lies with individual women". The primary responsibility of physicians, other health professionals and government public health agencies is education and ensuring that screening programs are available, are of adequate quality, and that cervical smears are obtained at an appropriate frequency. Responsibility for the development of larger laboratories and central registries require decisions by provincial governments. Professional associations and universities have the responsibility of persuading the health professions and the public that screening is important and that the recommended frequency of examination is a reasonable thing to do.

Discussions were held in the course of this study with senior representatives of the British Columbia Ministry of Health and the Cancer Control Agency of British Columbia. These discussions provided the following account of the original decisions to implement a screening program and subsequent decision to expand and modify the program:

The potential benefit theoretically derivable from early detection of cervical cancer was recognized by Dr. D. Boyes and his associates in the early 1950's. With funding from the Canadian Cancer Society, technologists were trained and an experimental exploratory program initiated. By 1955 it was apparent that in situ cancer could be detected by cytological scans. At this time however the need for controlled testing to establish the true efficacy of the technique in preventing progression to a clinical stage was not recognized. In 1955 the key proponents of the screening technique applied for and received long-term (10 year) federal-provincial funding support to establish a provincial laboratory. This development and subsequent expansion have had the clear support of the British Columbia Medical Association and the Faculty of Medicine at the University of British Columbia.

A unique aspect of the B.C. screening program is that the laboratory is centralized and operated by a government agency.

The pathologists of the Province of British Columbia have, at times, challenged the role of a government agency in providing such services but over time have acquiesced to this role.

Quoting Dr. Boyes (Boyes 1985):

"We were fortunate in starting the program at a time when it was philosophically acceptable. It probably would not be today. If one attempted it today, one would be beset by so

many critical epidemiologists demanding controls that funding would likely not be forthcoming."

It is apparent that provincial funding support was provided at a fairly prosperous time when economic analysis of such funding proposals was not conducted. The funding proposal was based on five years of data and on a logical concept; there was a need expressed for a long-range commitment to permit measurement of results.

The results evidenced by the British Columbia program and other provincial programs were challenged by a few epidemiologists in the early 1970's. This challenge led to the convening of the first Federal-Provincial Task Force on Cervical Cancer Screening Programs (Walton et al 1976). The Task Force concluded that, in Canada, "cytologic screening programs are becoming effective in reducing mortality from carcinoma of the cervix" and that "health authorities encourage and support the development of cytologic screening programs". The Task Force was reconvened in 1980 to examine new data and modify conclusions and recommendations where appropriate. The Task Force again concluded that there is evidence that screening is effective in reducing the incidence of invasive cancer of the cervix and mortality from the disease. It is notable that the reconvened Task Force reviewed a number of objective models designed to answer questions of cost-effectiveness and optimal resource allocation. The Task Force did not however attempt to conduct either a cost-effectiveness or cost-benefit analysis in support of its deliberations. These approaches have also not been applied in the province of British Columbia.

The following extract from the reconvened Task Force Report (Walton et al 1982) summarizes the current situation where professional judgement and socio-political pressures must necessarily be combined with quantitative analysis to support decisions on public expenditures on screening programs:

"Lacking any valid method to adequately distinguish those women destined to develop and die from invasive cancer of the cervix from those who will develop curable invasive cancer or never develop the disease, it becomes a matter of judgement, to which the public as well as medical scientists should contribute, how much in the way of resources should be invested in screening programs."

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Appendix 1.1 Cervical Cancer Screening in Other Canadian Provinces

Screening activities in provinces other than British Columbia occurred randomly, influenced largely by the leadership of British Columbia and through the collegial network of cytopathologists and gynecologists. The activities of a federal/provincial Task Force on screening in the early 1970s strengthened these relationships and led to new initiatives in a number of provinces (E. Kassirer, pers. comm.; Dr. D. Thompson, pers. comm.).

While most of the provinces had significant screening programs by 1966, the coverage of the female population 20 years or more varied considerably between provinces. Table 1-1 presented in Section 1.1.1 depicts the coverage of cytological screening in Canada of women aged 20 years and over for 1971, 1975, 1977 and 1979. The figures are based on the number of cytologic examinations (not the number of women screened) in each province, as determined in a survey by the Canadian Society of Cytology. From the table it can be observed that there was a substantial increase in Quebec and the Atlantic provinces in the number of examinations performed up to the mid-70s. Also, there appears to be remarkable uniformity across the country, with the exception of British Columbia where the proportion screened was still higher. By the early 1980s, British Columbia had reached 85% coverage of their female population 20 years and over.

Mechanisms for follow-up of women with abnormal smears and long-term follow-up following treatment of an abnormality are part of a successful screening program for cervical cancer. All provinces except Prince Edward Island, New Brunswick and Saskatchewan had developed follow-up mechanisms prior to 1976. In some provinces, the follow-up mechanisms included province-wide registries to facilitate effective follow-up, monitor coverage and collect data for epidemiological studies for purposes of evaluating the pattern of the disease and the on-going efficacy of the program. Specifically, Newfoundland, Manitoba and British Columbia had province-wide cytology registries prior to 1976, although Manitoba closed its registry in 1976.

Subsequently registries were set up in Prince Edward Island, Nova Scotia, Ontario and Alberta. In Quebec, two large laboratories have established registries, but they do not cover the total population of the province (Kassirer 1980).

Federal/Provincial Task Force on Screening for Cervical Cancer

In December 1973, a task force was established by the Conference of Deputy Ministers of Health to establish the value of cervical screening programs in the prevention of death among Canadian women from cancer of the cervix.

Members of the task force were selected by officers of the Department of National Health and Welfare from a group of 30 proposed in response to invitations issued by HWC to the Canadian Society of Pathologists, the Canadian Medical Association, the Society of Obstetricians and Gynaecologists of Canada, l'Association des médecins de langue française du Canada, the

Canadian Nurses' Association, and the provincial deputy ministers of health. Seven task force members were selected including Dr. Walton, the chairman of the task force, professor of the University of Manitoba and vice-president, Medical, Health Sciences Centre, Winnipeg.

At the initial meeting, there was some disagreement among members concerning the efficacy of cervical screening programs; however, such disagreement was resolved by the analyses of data (Canadian and European) and many hours of deliberation.

Once efficacy was established, the task force turned to questions of increased effectiveness and efficiency of the screening programs (Walton *et al* 1976). For example, recommended screening would be based on level of risk rather than on the customary practice of the "annual" pap smear for all women twenty years and more. Women over 18 "at risk" (sexually active female) should have an initial Pap smear. If the initial smear is negative, a second smear should be taken one year later. If both smears are satisfactory and negative, subsequent Pap smears should be taken at three-year intervals until the age of 35, then at five-year intervals until the age of 60. If all Pap smears during the life of the patient are negative by the time she reaches 60, then the patient can be dropped from the screening program. The report did recognize a group of women who were at increased risk for development of cervical cancer (the outset of sexual activity commences in mid-adolescence and with multiple sexual partners). The women at continued high risk should be screened annually.

Other recommendations made by the Task Force dealt with matters such as quality control and efficiency in cytology laboratories and on follow-up mechanisms, including the requirements for provincial registries.

In 1980, the 1976 Canadian Task Force was reconvened by Health and Welfare Canada in response to concerns expressed about the significance of new data, changing socio-sexual patterns and wide variation in the implementation of the 1976 recommendations. Specifically, their mandate was to review the recommendations of the 1976 report in light of new data and to confirm or change the original conclusions and recommendations and to arrive at new conclusions and make new recommendations if appropriate.

In the end, the recommendations of the reconvened Task Force reported in 1982 (Walton *et al* 1982) were similar to those in the 1976 report. Their analyses were based on data from international literature and on data from published and unpublished Canadian documents, and responses to the 1976 report by the Canadian professional community.

On the issue of frequency of screening, perhaps the most controversial recommendation (Morgan 1982), the reconvened Task Force reverted to annual screening instead of screening every three years for those under 35 years of age with previous negative smears considered "at risk". This change was based on new epidemiological evidence on the natural history of the disease and the changing sexual practices of women in the 1970s. Given that the majority of women under 35 years now do have multiple sexual partners, the group

considered at increased risk in the 1976 report (those with multiple sexual partners) became the "at risk" group in the 1982 report.

Members of the task force also concluded that if further progress was to be made in decreasing mortality from the disease, the level of participation in screening programs must be increased, and adequate quality of screening must be achieved and maintained. Moreover, the deployment of resources to concentrate on women at risk who presently are not being screened at all will permit screening programs to become more effective without utilizing more resources than they do at present.

Appendix 1.2 General Evidence of Screening Effectiveness from the Literature

The theoretical analysis of cervical cancer screening, based on assumptions of progression, diagnostic precision and treatment success suggest that cytological screening should be effective in reducing incidence of and mortality from invasive cervical cancer. (See Knox 1973, Eddy and Schwartz 1982).

It is generally accepted now that the only way to empirically establish beyond doubt that screening is effective in reducing invasive cancer incidence and mortality is to conduct a randomized trial. In such a trial asymptomatic individuals are recruited and assigned at random to either a screened group or a control group. Both groups are followed up and the mortality among the screened group (including those who do not accept the offer of screening) is compared with the mortality among the control group. Such trials have been conducted for breast and lung cancer screening, and trials of screening for colorectal cancer are underway. The Pap smear however was introduced before the need for randomized trials was fully understood, and it is unlikely that such a trial will ever be mounted given the ethical question of maintaining an unscreened control group. Without such a trial any apparent benefit observed among screened individuals could be due to one or more sources of bias, for example lead-time bias, length-based sampling bias, or selection bias. For details see Miller (1985) or Eddy and Schwartz (1982).

Despite the absence of a randomized trial, there are a number of studies based on observational data and statistical influence which suggest an association between screening and reduced mortality and incidence.

These studies are of four types:

- (i) time trends in incidence or mortality in areas with intensive screening;
- (ii) comparisons of incidence or mortality between areas with different intensities of screening;
- (iii) comparisons of the screening histories of women with cancer of the cervix and controls (case-control studies);
- (iv) comparisons of the incidence of cancer among screened and unscreened women (cohort studies).

The data on time trends in areas with intensive screening have been summarized by Prorok (1980). Incidence and mortality data were reviewed from nine screening programs in Canada, U.S.A., Iceland and Scandinavia. The data indicated a wide variation in initial rates as well as trends. In a number of instances, there are data available for both pre-screening and post-commencement of screening periods. In almost all instances, there has been a reduction in cervical cancer incidence rate after commencement of the program. Such before and after studies however are complicated by three

factors: trends in incidence and mortality occur irrespective of screening due to changes in the prevalence of risk factors, chiefly related to promiscuity; screening can produce changes in reported incidence due to the detection of prevalence cases and possibly also mis-diagnosis; trends in mortality are unreliable due to lack of distinction between cancer of the cervix and other uterine cancer. It is therefore difficult to isolate the effect of screening.

Most work on correlating changes in mortality with intensity of screening in different areas has been done in Canada, comparing different provinces. The earliest study by Ahluwalia and Doll (1968) showed no correlation, but this was probably because it was done too soon due to the considerable lag between screening and death. A later study by Miller, Lindsay and Hill (1976) found a positive correlation between the fall in mortality during the 1960s and screening intensity. However, when Miller, Visentin and Howe (1981) extended the analysis to the mid-1970s, the correlation disappeared. They suggested that this could be explained by a saturation effect due to repeat examinations rather than extension to unscreened women. Gardner and Lyon (1977) found no correlation in the United States. Other descriptive studies are summarized in the report of the reconvened Canadian Task Force on Cervical Cancer Screening Programs (Walton et al 1982).

Studies on individual women (case-control and cohort studies) have been summarized recently by Day and Moss (1986). The results of this review show a convincing negative association between invasive disease and a pap smear within the past six years, the relative protection decreasing as the interval since the last smear increases. It must be emphasized, however, that this association does not prove a causal relationship between screening and reduced incidence, even though some studies have adjusted for confounding factors.

The conclusion drawn from the literature with respect to efficacy of cytological screening can be summarized as follows:

There is substantial inferential evidence from worldwide experience that screening has contributed to a reduction of incidence of invasive cervical cancer and mortality below those levels which might have been experienced in the absence of screening. Thus the general question of efficacy was not a major issue in the deliberations of the 1981-82 Canadian Task Force. What is of key issue is the magnitude of effect, particularly marginal effectiveness in relation to the marginal input of screening resources (e.g. screening frequency).

CASE STUDY NUMBER 2

RAIL CROSSING SIGNAL IMPROVEMENT

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2. RAIL CROSSING SIGNAL IMPROVEMENT

2.1 Introduction

This study describes efforts made in Canada to reduce loss of life and property due to accidents at highway-railway crossings through expenditures on automatic protective devices such as flashing lights and bells as well as gates.

A substantial number of people are killed or injured each year in Canada at level railway crossings and the damage to motor vehicle, railway and third party property is significant. In addition to the personal and family hardship inflicted, such accidents also bring economic loss due to disruption of highway and rail movements, loss of earning power, and requirements for extended care.

The purpose of this case study is to review and present evidence of the contribution that improvements to signalling make to the reduction of risk of accidents at level railway crossings. In addition, the legislation, decision making processes, and expenditures involved in signal improvement have also been reviewed and analyzed. Finally an estimate of expenditures per unit risk reduction is derived.

2.1.1 Background and History: The Railway Grade Crossing Fund

In Canada, the Railway Act gives the Canadian Transport Commission (CTC) virtually absolute jurisdiction in the regulation of railways and, additionally, in the protection of the public at railway-highway grade crossings (hereinafter called 'crossings'). Section 192 of the Railway Act makes the CTC responsible for crossings. Although the CTC can legally order a municipality to fund or co-fund a signalling upgrade, it very seldom does so without first obtaining its consent. The CTC does not have jurisdiction over the signage, grade, paint markings or other characteristics of the road - this is vested in the road authority which, in turn, is influenced by the level of government which owns and maintains the road.

Federal responsibility for railway safety and for crossing safety stems back to the 1903 Railway Act and to the 1905 establishment of the Board of Railways and Canals. This agency later became known as the Board of Transport Commissioners and, in 1967, the Canadian Transport Commission. From 1880 to 1920 railway crossing safety was a very ad-hoc affair with little sustained activity on the part of any of the major players, although federal funds for signal upgrades have been available since approximately 1909.

The railway had unquestioned right of way due to:

- the importance of rail transportation to the nation;

- the railway was both the senior user and the more frequent user at many crossings; and
- horse-based transport had previously experienced considerably less trouble with trains (due to the rarity of a horse who could be driven into a train conflict situation).

There are now some 36,000 grade crossings in Canada of which slightly more than 32,000 are public crossings (i.e., the road is under jurisdiction of a public road authority and is therefore a highway as defined, for example, in the Ontario Highway Traffic Act or is at least publicly accessible). The Railway Grade Crossing Fund (RGCF), administered by the CTC and funded entirely by the federal government, is used to co-fund crossing signalling upgrades. Usually the RGCF pays 80%, the municipality or road authority 12.5% and the railway 7.5% of the direct cost of the upgrade. Maintenance is usually shared 50/50 between the railway and municipality.

When a crossing accident results in an injury or fatality, the CTC automatically places a slow order on the crossing, permitting the railway to operate at only 15 mph until it is lifted. The CTC carries out a post-accident inspection and may lift the slow order at that time or investigate a protection upgrade. In the latter case, the slow order usually stays on until further action is taken.

In most cases the CTC takes the initiative for an upgrade by approaching the railway and municipality. The railway is reminded that a slow order remains on the crossing and asked to prepare a plan, as discussed above. Usually, CTC regional engineers, railway signal personnel and an engineer or planner from the municipality will inspect the site together and discuss the proposed upgrade.

The railway usually prepares the signal upgrade. The CTC will review the plan thoroughly, while municipal review ranges from detailed to nominal. The municipality will prepare the road plan and all three parties must then approve both plans and the railway's cost estimate. Maintenance is normally shared on a 50/50 basis by the railway and municipality, but in certain cases where the railway expands its number of tracks or changes train speed, volume of traffic or other operating parameters, the railway will not be able to obtain CTC funding or municipal funding. In unusual circumstances, where the municipality alone spurs a crossing upgrade or modifications are due solely to road changes, the CTC may apportion more than 12.5% of capital cost to the local government and may also allocate up to 100% of the cost of maintenance to the local government.

2.1.2 Nature of the Hazard

In 1984 there were 595 reportable grade crossing accidents of which 563 occurred at public crossings. Of this latter figure some two-thirds occurred in either Ontario, Quebec or Alberta. This represented, respectively, 3.8 accidents per protected crossing and 1.3 accidents per unprotected crossing.

One-quarter of the accidents occurred in winter months with daily peaks in accidents occurring mid-day, during afternoon rush hour and very late at night (just after the bars close). The 563 accidents resulted in 292 injuries and 69 fatalities. In about 60% of cases the train hit the motor vehicle and in 40% the opposite was true. Although only some 25% of motor vehicles were trucks, 33% of the accidents involved trucks. It is believed that this is due both to driver behaviour and to truck stopping characteristics (CTC 1984).

Table 2-1 shows that the number of accidents at crossings has been steadily declining since the early 1970s. In a recent study of accident records (McLaughlin et al 1985) it was noted that:

- Roughly 20% of all railway accidents occur at railway crossings;
- Typically between 40% and 50% of crossing accidents result in a casualty (death or injury);
- Although only 20% of railway accidents occur at crossings, from 50% to 60% of railway accident-related deaths occur at crossings, thus indicating the severity of these accidents; and
- Over the last decade roughly 95% of deaths in crossing accidents involved motor vehicle occupants while 80% to 90% of injuries involved such occupants.

The average cost of a crossing accident has recently been estimated at approximately \$100,000 (CTC 1985), including a societal cost of \$845,000 ascribed to each death.

Although accidents have been decreasing over recent years, the decrease in injuries and deaths has been even more marked. It is believed by many observers that signalling upgrades not only reduce accidents but also reduce the severity of those that do occur. Some 50% of the casualties (injuries or deaths) occurred at protected crossings (which represent only 25% of total crossings) but these crossings have higher traffic, in most cases, than unprotected ones.

The standard minimal form of warning to motor vehicles of a railway crossing is the crossbuck. A crossbuck is the 'X' formation sign with the words 'railway' and 'crossing' written on the two sections. In addition to crossbucks, three types of signal protection are discussed in this report. They are:

- flashing lights and bells;
- wigwags - a moving arm device, now obsolete and almost extinct in North American railway operations; and
- gates, which includes the flashing light and bell, and which blocks each approach lane.

Table 2-1: Trends in Accidents at Rail Crossings in Canada

Year	No. of Accidents ¹	No. of Casualty Accidents ²	Casualties	
			Killed	Injured
1983	568	242	58	285
1982	691	281	77	357
1981	763	318	82	451
1980	826	352	83	435
1979	937	394	98	452
1978	871	336	89	415
1977	877	359	87	453
1976	923	428	108	524
1975	982	419	99	566
1974	1,074	472	114	664
1973	1,030	464	155	654
1972	1,175	562	159	681
1971	1,038	477	126	651
1970	977	433	119	581

Source: McLaughlin et al, 1985. From accident reports of the Rail Transport Committee.

Notes: ¹ Time trends post-1980 are based on a different reporting method than pre-1981.

² A casualty accident is defined as one in which persons, either in the train or vehicle, have been either killed or injured.

Of the 32,062 public crossings in Canada, there are 23,455 crossbuck crossings (73%), 6,845 flashing light and bell crossings (21%), only 1,035 with gate protection (3%) and 3% with no protection. Thus 73% of crossings are 'unprotected' by signals. In Ontario, the situation is somewhat different with 4,832 crossbuck (57%), 2,259 flashing light and bell (29%) but only 696 gate (9%) crossings (CTC, 1985).

Further information on the U.S. experience in analyzing rail-vehicle accidents is provided in Appendix 2.1.

2.1.3 Objectives and Scope

The objectives of this study are to:

- (i) document the effect that signal upgrading has had on reducing accidents;
- (ii) determine the direct and associated costs of installing and maintaining signal upgrades;
- (iii) derive an estimate of average expenditures per unit of risk reduction; and
- (iv) describe the mandates, processes, and rationales underlying decisions on expenditures for signal improvement.

The case study is limited to:

- (i) crossings located in the Province of Ontario;
- (ii) data collected for the periods 1971 to 1984; and
- (iii) only improvements and upgrades of automatic protection devices for railway crossings are examined. Grade separation, alignment changes and vision improvement measures are not included. The improvements and upgrades examined include:
 - crossbuck to flashing lights and bells;
 - flashing light and bell improvements; and
 - flashing lights and bell to gates.

2.2 Methodology

2.2.1 Definition of Risk

As the basic measure of risk we adopted the number of accidents per million units of the product of vehicle traffic volume multiplied by train traffic volume (hereinafter referred to as traffic volume product). This approach allows for standardized comparisons of crossings with vastly different traffic

volumes. The number of injuries or fatalities per million units traffic volume product is also examined.

2.2.2 Documentation of Risk Reduction

The main methods used to document risk reduction were:

- a review of the general literature relating to the effectiveness of signal upgrades in Canada and in other jurisdictions; and
- detailed analysis of CTC accident data for selected Ontario crossings.

The CTC maintains data on the accidents which occur at each crossing in Canada as well as on injuries and deaths where applicable. Detailed crossing characteristics profiles are also maintained, as are details of upgrade orders and pertinent financial commitments. Risk reduction was measured for selected crossings as the historical change in accident frequency before (five years) and after (five years) a signal upgrade had been made.

In selecting an appropriate timeframe for this study the study team was constrained by two important factors:

- availability of reasonably recent, consistent and accurate data; and
- feasibility to perform five year pre/post analyses.

With 1984 as the latest complete year of accident data, at the time data was being collected for this study, 1979 was selected as the most recent upgrade year which could be considered. Recognizing the need to use more than one upgrade year to allow for any particular climatic or other variations, as well as variations in RGCF funding, upgrades in the years 1975-1979 inclusive were selected for study.

In selecting crossings for detailed analysis, it was decided to use a limited time frame and a limited geographic area (i.e. Ontario), which allowed control of the number of crossings and selection of crossings with similar operating conditions. Emphasis was also placed on using the least biased crossing selection method possible. Upgraded crossings were compared to each other and non-upgraded crossings. Looking at balanced five-year pre/post upgrade periods, the number of crossings with decreased, equal and increased numbers of accidents were observed. Based on this analysis, 606 crossings were selected for detailed analysis. These selected crossings have each had two or more accidents.

The subsets of these crossings are as follows:

Single Upgrade crossings (116) experienced one single upgrade in the 1975-1979 period. The five-year pre-time series includes the actual year of upgrade as crossings are often upgraded after a serious accident in the same year as that

accident. Ignoring any accidents in the year of upgrade would distort the data. The five-year post- period is for the five years following the upgrade.

Double Upgrade crossings had two upgrades within the designated years which were either in contiguous years or were separated by one year.

Late Upgrade crossings were upgraded once during 1980-1982 and hence do not allow for a pre- and post-upgrade analysis.

Never Upgraded crossings (459) were not upgraded within the 1975-1979 period or thereafter. Some such crossings may have been upgraded since 1983-1985, after the study period. This group also include:

- crossings upgraded before 1975; and
- crossings which achieved grade separations, reducing risk to 0.

An analysis of the data indicated that four crossings were impacted by grade separation, six were upgraded two or more times and 21 were upgraded after 1980, therefore not allowing five-year pre and post analysis.

A database was established to allow organization of accident, limited crossing profile and upgrade type and cost data to allow analysis and correlation.

2.2.3 Collection of Expenditure Data

As noted earlier, expenditures on crossing protection devices are shared by:

- Canadian Transport Commission: 80% of direct capital cost from the Railway Grade Crossing Fund;
- Local municipality or road authority: 12.5% of direct capital cost and usually 50.0% of maintenance cost; and
- Railway: 7.5% of direct capital cost and usually 50.0% of maintenance cost.

CTC financial data on financial commitments (which are virtually always for 80% of the estimated direct cost of the upgrade) were obtained for the desired period and crossings. Costs were multiplied by 1.25 to obtain a working estimate of direct upgrade cost.

In four of 16 cases where files were reviewed variances of 2 to 4% in the final amount were found due to differences in the estimated and final amounts. Sometimes additional municipal work was not counted under the CTC order costing, and this may have resulted in additional improvements to the crossing road approaches, signage, etc.

All commitments have been expressed in the dollar values of the year in which the upgrading took place, with no allowance for inflation. It is assumed that

average costs as measured over the 1975-1979 period can reasonably be interpreted in terms of 1977\$. No annual maintenance costs are included in the basic costing, however, these are estimated to range from 5 to 10 percent of capital costs; in most cases the former figure is more accurate.

The direct costing also does not include CTC, railway or municipal planning or administrative costs. Instead a simple conceptual model with a total-to-funded ratio was developed. Differential cost ratios were not considered to be a major factor.

2.2.4 Determination of Expenditure Rationales

To obtain an understanding of the basis and rationales underlying decisions on upgrade expenditures, interviews were held with representatives of the Canadian Transport Commission and selected municipalities in which upgrades have recently occurred. A request for participation was sent out to 16 municipal road authorities in Ontario; locations were selected to provide a mix of urban and rural environs. A total of 15 organizations responded to the request for a structured telephone interview.

2.3 Results

2.3.1 Evidence of Risk Reduction at Selected Ontario Rail Crossings

Table 2-2 breaks down the number of upgrade crossings in each category which experienced increased, equal or decreased accidents when the balanced five year pre/post periods are compared. In the Single Upgrade group, 95 of a total of 116 (81.8%) of the crossings which were upgraded indicated a decrease in accidents while 15 crossings (12.9%) were equal and 6 (5.17%) had increases in accidents. The other two groups had similar, but less pronounced, trends toward reduced accidents.

Yearly accident-injured-killed data for the total upgraded crossing group are provided in Table 2-3. This time series demonstrates an accident peak of 101 in 1974 and a low of 9 accidents in 1984. It is apparent that the cumulative impact of more and more upgrades can be seen as the group exhibits a downward trend in all but the 1978-1979 and 1982-1983 periods.

The number of accidents has also decreased at the Never Upgraded crossings, as shown in Table 2-4. Although it is difficult to fully explain the reasons for overall accident reduction, the following may be worthy of consideration:

- There may be a unique-to-Ontario phenomenon affecting some or most of the Never Upgraded crossings over this period, however the number of accidents has been falling nationally for no proven reason.

- Motorist behaviour has, it is believed, been influenced by the Operation Lifesaver (post-1980) project initiated by the Canadian Railway Association; this would have an effect on all crossings including upgraded ones.

Table 2-2: Accidents in Balanced Pre/Post Upgrade Periods

TYPE OF UPGRADE	NUMBER OF CROSSINGS WITH:			TOTAL # OF ACCIDENTS
	DECREASED # OF ACCIDENTS	EQUAL # OF ACCIDENTS	INCREASED # OF ACCIDENTS	
SINGLE UPGRADE	95 (81.89%)	15 (12.93%)	6 (5.17%)	116
DOUBLE UPGRADE	5 (83.33%)	0	1 (16.66%)	6
LATE UPGRADE	18 (85.71%)	1 (4.76%)	2 (9.52%)	21
TOTAL	118 (82.51%)	16 (11.18%)	9 (6.29%)	143

This table indicates the number of crossings within each category which demonstrated an increased, constant or decreased number of accidents in the five-year period after an upgrade.

Table 2-3: Upgraded Crossing Data by Year

YEAR	# ACCIDENTS	# PERSONS INJURED	# PERSON KILLED
71	52	23	3
72	81	56	12
73	63	26	7
74	101	77	12
75	63	31	5
76	57	42	8
77	55	45	6
78	35	18	6
79	37	19	2
80	28	16	1
81	24	16	2
82	13	4	2
83	20	4	1
84	9	1	6
TOTAL	638	378	72

This table indicates the number of accidents, injuries and deaths which occurred at all crossings within the 'upgraded' group over the 1971-1984 period. Note that there is a cumulative impact of upgrades over the period, as more and more crossings are improved.

TOTAL SAMPLE SIZE = 143 crossings

Table 2-4: Accidents at Crossings Not Upgraded

YEAR	ACCIDENTS
71	184
72	206
73	172
74	149
75	144
76	143
77	129
78	122
79	126
80	64
81	64
82	30
83	30
84	29
TOTAL	1592

This data indicates that accidents were falling even at crossings which were not upgraded during our study period. The impacts of the Operation Lifesaver program (post-1980) of upgrades to approaches or road signage (which were not specifically studied) and of other factors may have impacted this trend.

TOTAL SAMPLE SIZE = 459 crossings

- It is possible that a very substantial percentage of these crossings experienced some other type of physical upgrade than that normally funded by the CTC, improving safety.

It noted that the much smaller Single Upgraded group (roughly one-quarter the size of the Never Upgraded group) exhibits a larger accident decrease in absolute and relative terms between 1975 and 1979 than does the Never Upgraded group; these are the years in which investment was being made in the Single Upgraded crossings. The Never Upgraded group, however, has large decreases in the 1979-1980 and 1981-1982 periods (126 to 64 and 64 to 30) which are not reflected in the Single Upgraded group.

Although the geographical distribution of the Single and Never Upgraded crossings throughout Ontario is basically similar, it is by no means identical. Accordingly, it was decided to establish a control group of crossings, to be drawn from the Never Upgraded set, and to reflect the geographical distribution and other characteristics of the Single Upgraded set.

Spot checks were made on traffic volume product data and other characteristics using the Ontario crossing profile printout prior to committing to this approach. The new set was designated the No Upgrade Surrogate set of crossings.

Calculation of pre-upgrade and post-upgrade accident frequency was conducted for the No Upgrade Surrogate crossings in precisely the same way as for the Single Upgrade crossings; Table 2-5 provides a yearly breakdown of Single Upgrade while the same data is provided for No Upgrade Surrogate in Table 2-6. Note the substantial difference in the totals of decreasing, equal and increasing accident crossings between the two tables. Overall percentage of crossings with decreases was 81.9% for Single Upgrade and only 55.2% for No Upgrade. Single Upgrade crossings also fare better in each individual year than do No Upgrade ones. Table 2-7 provides comparisons for the periods before and after the upgrading period of 1975-1979 and these show that despite the fact that there were more Single Upgrade accidents before upgrading started, the relative and absolute decreases were larger on the Single Upgrade side. Single Upgrade accidents decreased by both a better absolute (235 accidents) and a better percentage figure. The comparative percentage reductions were 72.75% for Single Upgrade and 28.90% for No Upgrade.

These data indicate that despite the trend downward in accidents at non-upgraded crossings it is evident that there is an incremental effect of signal upgrading.

2.3.2 Expenditures on Risk Reduction

Table 2-8 provides information on the direct upgrade costs (the cost of final engineering, equipment purchase, installation and checkout by the railway prior to CTC inspection) by crossing category. The minimum costs presented in this table are very low due to the fact that many upgrades in the flashing

Table 2-5: Single Upgrade Crossings
Accidents in Balanced Pre/Post Upgrade Periods
By Year of Upgrade

YEAR	TOTAL # OF CROSSINGS	NUMBER OF CROSSINGS WITH:		
		DECREASED # OF ACCIDENTS	EQUAL # OF ACCIDENTS	INCREASED # OF ACCIDENTS
75	36	27 (75.0%)	7 (19.4%)	2 (5.5%)
76	31	27 (87.1%)	3 (9.7%)	1 (3.2%)
77	16	12 (75.0%)	2 (12.5%)	2 (12.5%)
78	12	10 (83.3%)	2 (16.7%)	0 (0.0%)
79	21	19 (90.5%)	1 (4.8%)	1 (4.8%)
TOTAL	116	95 (81.9%)	15 (12.9%)	6 (5.2%)

This table indicates the number of crossings in the Single Upgrade category which demonstrated an increased, even or decreased number of accidents in balanced 5 year periods before and after the upgrade.

Numbers in brackets show percentage.

Table 2-6: Non Upgrade Surrogate Crossings (NUX Group)
Accidents in Balanced Pre/Post Nominal Periods
By Nominal Year

YEAR	TOTAL # OF CROSSINGS	NUMBER OF CROSSINGS WITH:		
		DECREASED # OF ACCIDENTS	EQUAL # OF ACCIDENTS	INCREASED # OF ACCIDENTS
75	36	16 (44.4%)	8 (22.2%)	12 (33.3%)
76	31	19 (61.3%)	3 (9.7%)	9 (29.0%)
77	16	9 (56.3%)	3 (18.8%)	4 (25.0%)
78	12	7 (58.3%)	2 (16.7%)	3 (25.0%)
79	21	13 (61.9%)	5 (23.8%)	1 (14.3%)
TOTAL	116	64 (55.2%)	21 (18.1%)	31 (26.7%)

This table indicates the number of crossings in the No Upgrade category which demonstrated an increased, equal or decreased number of accidents in balanced five-year periods before and after the nominal year of that particular crossing. The nominal year is defined as the year of upgrade at the Single Upgrade crossing for which an No Upgrade crossing is used as a mirror image.

Table 2-7: Single/Surrogate Upgrade Crossing Comparison

ACCIDENTS	SINGLE UPGRADE GROUP	SURROGATE GROUP
TOTAL NO. OF ACCIDENTS BY YEAR:		
1971	48	54
1972	76	57
1973	55	36
1974	90	45
71-74 TOTAL	269	192
71-74 AVERAGE	67.3	48.0
1980	19	25
1981	21	34
1982	10	16
1983	19	17
1984	8	14
80-84 TOTAL	77	106
80-84 AVERAGE	15.4	21.2
TOTAL NO. OF ACCIDENTS WITHIN 5 YEAR PERIODS:		
PRE-UPGRADE	323	211
POST-UPGRADE	88	150
REDUCTION	235	61

This table indicates that the Single Upgrade group of crossings, although more dangerous in total than the Never Upgrade Surrogate group before the 75-79 upgrade period, proved less dangerous afterwards - a marked decline in accident frequency is observed.

Table 2-8: Crossing Upgrade Direct Cost Data¹

COST RANGE	SINGLE UPGRADE	DOUBLE UPGRADE	LATER UPGRADE	ALL
TOTAL (all crossings)	\$2,431,093	\$154,876	\$841,640	\$3,331,496
AVERAGE (1977\$) (per upgrade)	20,957	25,811	40,078	23,397
MAXIMUM (per upgrade)	80,100	65,525	60,400	80,100
MINIMUM (per upgrade)	125	216	3,075	125
SAMPLE SIZE (number of crossings)	116	6	21	143

Note that all of these expenditures, except the Later Upgrade category, were made during the 1975-1979 period. It is assumed that average costs can be interpreted in terms of 1977\$.

Note: 1. Direct costs include engineering, equipment purchase, installation and checkout by the railway but not administration or maintenance costs.

light and bell category simply involved minor changes. The average of \$20,957 is, in the study team's opinion, a reasonable estimate of direct costs across the range of upgrade types and installation years. Recent (1980) data show averages in the \$35,000 to \$45,000 area.

Average direct costs by type of upgrade for single upgrades are presented in Table 2-9.

The administrative costs associated with crossing upgrades are estimated in Table 2-10 based on 1975-1979 information (dollar values adjusted by year) with salary levels rounded to the nearest \$1000 and then multiplied by 1.2 to cover all direct benefits. The information on time spent on a 'typical' crossing upgrade is based on file information, CTC officials' opinions and input from municipal representatives. Our example indicates total CTC, railway and municipal administrative costs are \$1473, \$386 and \$760 respectively. Table 2-11 incorporates these costs into the total cost of a typical upgrade including direct installation costs, administration, and annual maintenance for five years. A factor of 1.37 is derived to account for administration and maintenance costs.

2.3.3 Expenditures per Unit Risk Reduction

Risk reduction is measured as the absolute change in accidents per million units of traffic volume product from the pre- to post-upgrade period. Total costs per accident reduction is shown in Table 2-12. Crossbuck-to-flashing light and bell upgrades have the highest average cost of per accident reduction, calculated at \$16,458 while flashing light and bell is lowest at \$6,426. Flashing light and bell upgrades lie in between, at \$14,208. This table makes no reference to injuries or deaths, only to reductions in the numbers of accidents at crossings. The overall average cost per accident averted is calculated to be \$14,173 (then year, as spent \$).

The amount of risk reduction (post versus pre upgrade) per million units of traffic volume product of rail and road traffic volume was calculated for three groups of crossing:

- (i) single upgrade crossings with pre/post accident reduction
- (ii) single upgrade crossings with pre/post injury reduction
- (iii) single upgrade crossings with pre/post fatality reduction

Table 2-13 presents summary data on the cost of reducing risk of accident, injury or death for the crossings studies. (Note that data are provided for only those crossings in which a reduction in event occurred.) In each case the large standard deviation of the cost indicates a significant degree of variability in cost per unit reduction.

The average cost to reduce accidents by just one accident per million units of traffic volume product was \$2,163,779. This means that our average direct expenditure, for the crossings considered, of \$23,224 was buying an average of

Table 2-9: Direct Cost by Type of Upgrade Within the Single Upgrade Category (\$ of year spent)

UPGRADE TYPE	TOTAL	MINIMUM	MAXIMUM	AVERAGE	NO. CASES
CROSSBUCK TO FLASHING LIGHT AND BELL	\$1,621,774	\$14,000	\$80,100	\$27,029	60
CROSSBUCK TO GATE	67,450				1
WIGWAG TO FLASHING LIGHT AND BELL	43,800	21,800	22,000	21,900	2
WIGWAG TO GATE	128,733	26,333	52,000	42,911	3
FLASHING LIGHT AND BELL IMPROVEMENT	267,383	125	50,000	6,521	41
FLASHING LIGHT AND BELL TO GATE	300,753	24,000	55,000	37,594	8
GATE IMPROVEMENT	1,200				1
TOTAL (ALL TYPES)	\$2,431,093	125	\$80,100	\$20,957	116

This table indicates that 101 of 116 upgrades were either from crossbuck to flasher or were improvements to existing flasher. Note that the term 'flasher' is used to describe flashing light and bell equipment.

Table 2-10: Administrative Cost Outline (1975-1979)

PERSONNEL COSTS			CTC	RAILWAY	LOCAL
LEVEL	DAYS	ANNUAL			
Regional Engineer	3	\$45,000	\$ 540		
Regional Manager	.5	55,000	110		
Admin. Manager	1	40,000	160		
Signal Engineer	1	38,000	152		
Civil Engineer	.5	38,000	76		
Signal Supervisor	2	32,000		\$256	
Municipal Engineer	3	40,000			\$480
Municipal Admin.	2	35,000			280
TRAVEL COSTS					
Trips to site					
- 300 mi. x .30/mi	\$ 90				
- meals	40				
	\$130				
CTC (3 trips)			360		
Railway (1 trip)				130	
TELECOMMUNICATIONS					
15 calls					
Toronto-Ottawa					
10 min. average					
			75		
TOTAL			\$1,473	\$386	\$760

NOTE: All salary costs are 120% of nominal salary to individual.

Table 2-11: Typical Total Signal Upgrade Cost

ITEM	COST
Direct (shared) costs - site planning	
- circuit planning	
- site preparation	
- equipment purchase	
- installation	
- checkout	\$24,000
Railway non-invoicable administration	386
CTC administration (directly accountable to upgrade)	1,473
Municipal administration (directly accountable)	760
Maintenance (PV of 5 yr at \$1,500/yr at 10%)	6,256
TOTAL	\$32,875
$\text{TOTAL/DIRECT RATIO} = \frac{32,875}{24,000} = 1.37$	

This table indicates that the estimated total of administration and direct installation costs, plus maintenance, is about 37% greater than the direct cost itself assuming an operating period of five years to be consistent with the calculation of risk reduction. The \$2,619 in administrative costs is approximately 10.9% of direct cost.

Table 2-12: Upgrade Cost and Total Accident Reduction Within Single Upgrade Crossings

UPGRADE TYPE	NO. OF CASES	TOTAL DIRECT COSTS	TOTAL ALL COSTS ²	ACCIDENT REDUCTION ¹	TOTAL COST PER ACCIDENT REDUCTION ¹
CROSSBUCK TO FLASHING LIGHT AND BELL	60	\$1,621,774	\$2,221,830	135	\$16,458
FLASHING LIGHT AND BELL IMPROVEMENT	41	267,383	366,315	57	6,426
FLASHING LIGHT AND BELL TO GATE	8	300,753	412,032	29	14,208
OTHER	7	241,183	330,421	14	23,601
TOTAL	116	\$2,431,093	\$3,330,598	235	\$14,173

- Notes: 1. Accident reduction is calculated as total 5 year pre-upgrade accidents minus total 5 year post-upgrade accidents. The accident reduction presented is therefore distributed over 5 years.
2. Based on a factor of 1.37 to include administrative and maintenance costs.

Table 2-13: Cost of Risk Reduction - Selected Rail Crossing Upgrades

GROUP I	N ²	EVENT	TOTAL DIRECT COSTS	AVERAGE DIRECT COSTS PER CROSSING	DIRECT COST PER REDUCTION OF 1 EVENT PER 5 YEAR PERIOD ³	TOTAL ALL COSTS ⁴	TOTAL COST PER REDUCTION OF 1 EVENT PER 5 YEAR PERIOD PER MILLION UNITS OF TRAFFIC VOLUME PRODUCT
					MEAN	STD. DEV.	
I	100	accidents	\$2,322,400	\$23,244	\$12,561	\$13,729	\$3,181,688
II	59	injuries	\$1,237,203	\$21,817	\$12,534	\$14,517	\$1,763,468
III	21	fatalities	\$ 482,874	\$22,994	\$18,193	\$14,014	\$ 661,537
							\$5,674,763

Notes: 1. GROUP = set of crossings showing a reduction in event shown.

2. N = number of crossings in study sample group showing a reduction in events pre/post upgrade

3. Mean and standard deviation of cost per reduction of one event based on calculated reductions (5 year pre-upgrade minus 5 year post-upgrade) for N crossings. Cost is for reduction of one event over a five year period. The mean cost is per crossing unweighted by reduction per crossing.

4. Based on a factor of 1.37 to incorporate administrative and maintenance costs.

NOTE: costs are expressed in approximate 1977\$.

0.0147 accident reduction per million traffic volume product.

The cost to reduce the probability of injury by one event per million traffic volume product was \$3,225,498, equal to a reduction of 0.00926 injuries per million units of traffic volume product for the average expenditure on upgrade of \$21,817.

The cost to reduce the probability of fatality by one event per million traffic volume product was \$5,674,763. Given the average upgrade cost of \$22,994 at these crossings provides an average reduction of 0.00555 deaths per million traffic volume product.

2.4 Discussion

2.4.1 Reliability of Estimates

The results of this study are sensitive to the attribution of all risk reduction at upgraded crossings to the act of upgrading. As mentioned earlier, there is a concurrent downward trend in annual accident frequency at similar non-upgraded crossings. To the extent that this trend was independently in effect at upgraded crossings, the measured benefit of upgrading should be reduced (by up to 40%); this would have the effect of raising the cost per unit risk reduction by an inverse proportional amount.

2.4.2 Roles, Responsibilities and Rationales for Risk Reduction

Figure 2-1 provides a schematic representation of decision flow with respect to upgrades.

Figure 2-2 summarizes the pathways of input, influence and control found to underlie decisions on upgrade expenditure. As might be expected, there is a complex political economy which governs these decisions.

The following points summarize the results of interviews with CTC and municipal officials.

Canadian Transport Commission

Within the CTC, a subset of the politically appointed commissioners sit on the Railway Transport Committee (RTC). One commissioner chairs the committee which meets regularly to consider orders recommended by staff. The executive director of the committee is the senior public servant reporting directly to the chairman. Under the executive director are two directors general, one being responsible for the operations branch and one responsible for the engineering branch. The Accident Investigation and Services Division of the former and the Construction Division of the latter work together in dealing with crossing upgrade issues.

Figure 2-1: Generalized Upgrade Decision Flow

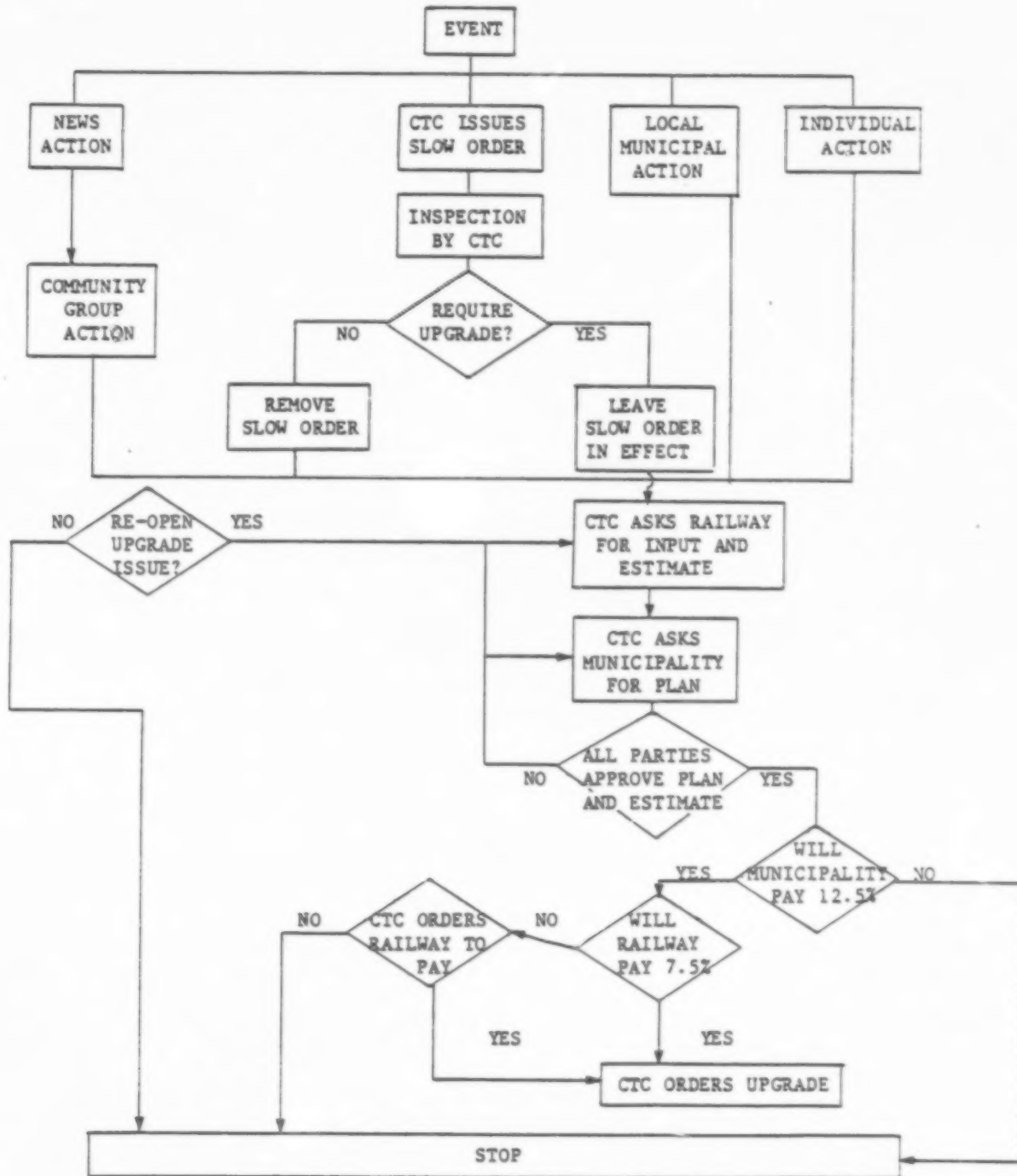
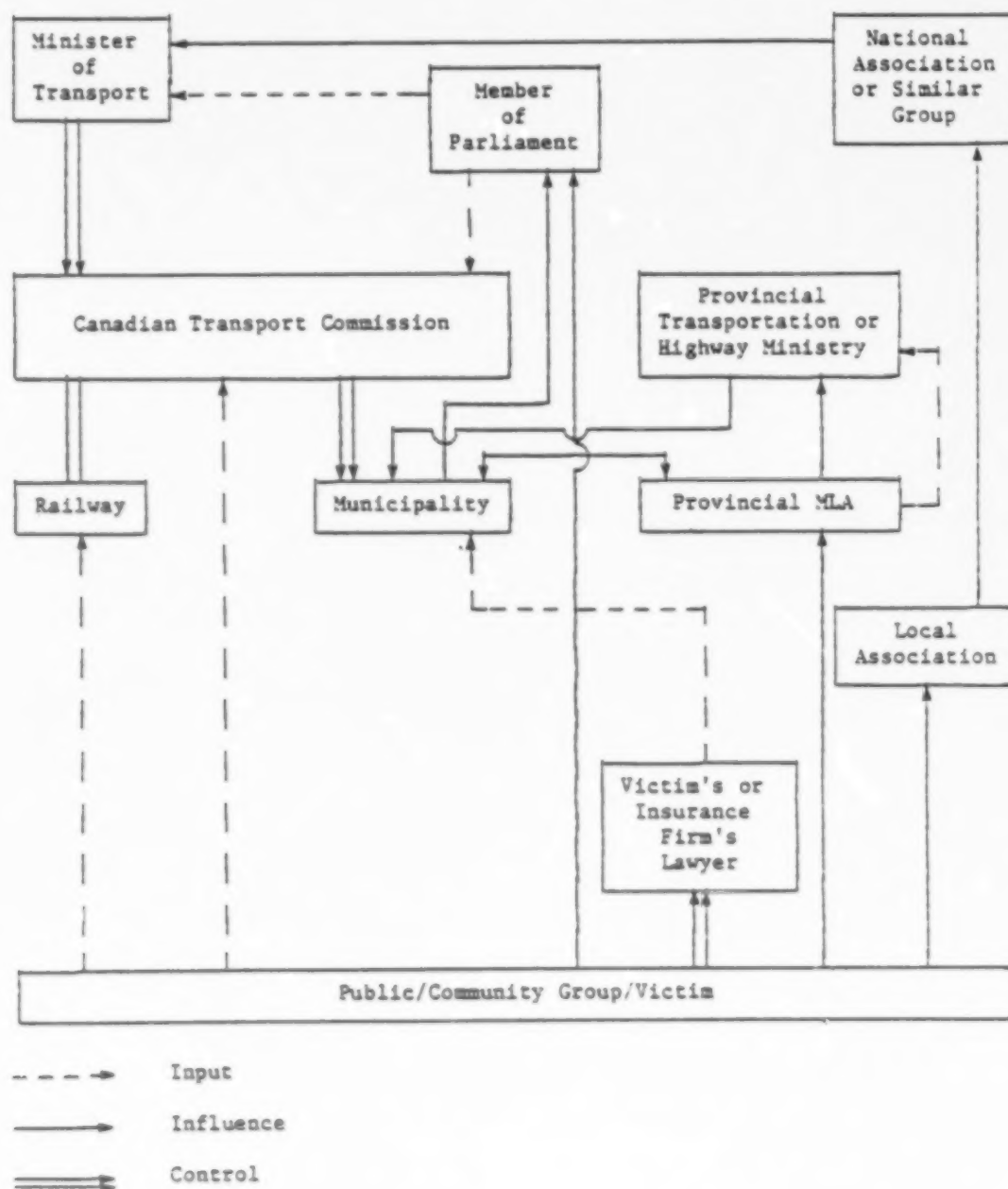


Figure 2-2: Jurisdictional/Political Relationships



The Railroad Grade Crossing Fund is provided with a fixed budget each year by Parliament, in the context of previous allocations, and the RTC cannot make commitments in excess of this amount. The study team was unable to obtain any formal internal guidelines for the distribution of RGCF funds and was told that they do not exist.

Recent information indicates that the RGCF is fully expended each year as the RTC continues funding upgrades until the funds are depleted. It was stated that in terms of Ontario, there is a five-year backlog of crossings which the CTC would like to upgrade but cannot fund. The CTC attempts to ensure that there is a national distribution of the money each year in proportion to relative need.

The criteria used by the RTC appear to have been in consistent use since the late 1940's. A situation of two or more accidents within a five-year period seems to be taken as a signal of danger but many such crossings exist which were never upgraded. A more significant parameter appears to be the occurrence of two or more accidents at a crossing within a twelve month period. It is also generally agreed that signals are required with a cross product of over 1000-1500, this involves a large number of crossings. It was stated that where the traffic volume product is over 50,000, gates should be considered, particularly if there are multiple lanes and/or tracks. Where there is significant school bus or tanker truck traffic, special consideration is also given. Further, if a municipality is particularly concerned and appropriates money for its 12.5% a crossing will be given consideration even if there has not been a recent accident or it does not meet the other qualifiers.

CTC officials indicated that political interference in grade crossing upgrade discussions is the exception rather than the rule. Information collected for this study indicated that in four of 16 cases there was evidence of involvement of the Member of Parliament or Minister of Transport.

The files indicate that the railways treat crossing upgrades in a relatively routine manner, with junior people signing virtually standard form letters on behalf of senior corporate counsel. The major railways do not appear proactive in anticipating which crossings may be growing more hazardous or in upgrading existing signalling; it would seem they view that as the CTC's role. Furthermore, the railways do not appear particularly motivated by the potential liability issue, possibly due to the relatively strong legal protection for their 'right of way' in Canada.

The CTC appears to go to considerable lengths to be reasonable and to avoid having to actually order a municipality to do anything it has not already consented to by (binding) letter to do. However, in many cases discussions about a crossing continue for months or even years, in at least six of our 16 cases another accident occurred while the first one, and its possible resultant upgrade, were still being discussed.

In conclusion, we can find virtually nothing to suggest that CTC application of the RGCF is not both reasonably fair and sensitive to local concerns. Full consultation almost always precedes the issuance of an order.

Municipal Road Authorities

Municipal authorities were asked questions regarding the impetus or motivation for the upgrade.

In 10 of 15 cases the municipality said they were the ones who initiated upgrade discussions; however, CTC file materials did not always allow verification, and in some cases actually contradicted municipal claims. Of the remainder, four said the CTC was the instigator of actions and one credited the railway. One jurisdiction said any crossing in its boundaries should be upgraded to at least flashing lights and bells while another had developed a sophisticated algorithm. The following were the reasons mentioned by the 10 initiating municipalities in requesting an upgrade:

- overview approach	1
- police reports	1
- visibility	2
- motor vehicle traffic	1
- traffic cross-product	4
- accident history	9
- CTC recommendations	2
- public opinion	2
- change in train speed	1
- change in road	1
- own inspection	1

The media were involved in providing basic coverage of accidents in nine cases but only in three municipalities were they viewed as campaigning for action. In five cases there was no media involvement. Petitions were a factor in certain municipalities and in about half of the cases some form of citizen action was a factor. Municipal opinion leaders or local politicians became actively involved in seven cases. Involvement by provincial or federal politicians was limited to four cases.

In providing their interpretations of the rationale used by the CTC in deciding on upgrades the following were indicated in these frequencies:

- obvious needs	1
- traffic volume product	3
- site survey	2
- complaints	1
- accident history	5
- CTC guidelines	1
- weighting of various aspects	1
- school bus present	1
- tanker truck present	1

- CTC upgrades all accident crossings 1
- not really sure 6

Several municipalities indicated they felt their opportunity for input to the process was inadequate, but were unsure how they would improve the situation. The railways received generally poor reviews; 10 of the 15 municipalities were unhappy with their involvement. The railways were characterized as 'sluggish', 'of very low profile', 'passive, slow and cheap', 'impossible' and as taking no action whatsoever until the CTC acted. The five municipalities finding the railways agreeable characterized them as concerned and relatively prompt in their responses.

Fourteen municipalities found the administrative and political machinations preceding the co-funding decision went smoothly; one did not. In the latter case, most of the debate was over the sharing of maintenance, not capital costs. Past accidents, overall safety considerations, the CTC's 80% funding share and the potential liability issue were the main issues discussed at senior administrative and political levels. Very few respondents considered the 12.5% a major hardship. Cross-product and accident data were the main information items presented to decision makers in quantitative terms, along with cost estimates. Police reports and CTC reports were reviewed by some councils. One jurisdiction hired external consultants to study and rank all crossings in their area but all others had engineers or roads superintendents perform the work leading up to political review. No jurisdiction approved the funds solely at the administrative level.

All but four jurisdictions took some additional, non-CTC funded, upgrading actions in the crossing area at the same general time as the signal upgrade. In many cases, these were in partial response not only to local concerns but also to CTC recommendations. The mention/frequency of upgrade items was as follows:

- change geometry 5
- change grade 5
- change signs 1
- paint pavement 2
- clear sightlines 2
- pave or upgrade 1

Fourteen of 15 municipalities felt accidents were reduced by the upgrade while one did not. The local opinions were generally in keeping with file and statistical information. None knew whether the upgrade had reduced near misses or other dangerous situations. Ten felt general awareness of danger as the crossing rose with the upgrade, two did not and three were unsure.

Eleven of 15 felt the public supported the upgrade, three were unsure and one thought the upgrading was excessive, in terms of public opinion. It was also stressed that recent changes to the Ontario Municipal Act will require hearings prior to municipal participation in such upgrades in many cases in the future.

Nine of 15 felt the RGCF was fair in its allocation of percentages among the key actors while four respondents thought the railway and municipality should each pay 10% of upgrade cost. Two had no opinion.

In two of 15 cases lawsuits concerning accidents at the crossing appear to have been initiated, but detailed information was unavailable. Virtually all respondents felt that it was increasingly the case that a municipality ignores a recommendation to co-fund and upgrade at its own risk. If an accident subsequently occurs at a crossing which is not only known to be dangerous but for which the CTC recommended an upgrade (but where the municipality refused to co-fund), a successful legal action for negligence is viewed as a realistic possibility.

In conclusion there is a wide variance in the identified bases or rationales used at the local level to decide whether to recommend co-funding or actually approve same but traffic volume product and accident history are by far the predominant factors. Local individuals and associations sometimes spur politicians to act but there are several cases with initiatives taken at the political level without identifiable pressure. Elected officials at higher levels tend to be consulted only when the process is delayed or otherwise frustrated. However, the CTC is generally praised for its thoroughness and patience.

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PERSONAL CONTACTS

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Appendix 2.1 United States Rail Accident Studies

A study conducted in the early 1970s in California surveyed 380 local governments regarding 1,552 crossings. It found four key factors in predicting crossing accident susceptibility:

- motor vehicle traffic;
- train traffic;
- quadrant visibility of crossing; and
- train speed.

In 1981, the U.S. Federal Railroad Administration (FRA) studied approximately 215,000 crossings and discovered that to upgrade each to full (gate) protection at an average cost of \$50,000 (U.S.) would cost more than \$10 billion (U.S.) and this was viewed as not politically feasible in the near term. An attempt was made to combine prediction of accidents with and without signals with signal effectiveness. An absolute formula was developed which estimated the number of accidents based on crossing characteristics and on actual historical data. Five year time horizons were used. The product of rail and vehicle traffic volumes was found to be the prime factor and six highway/crossing characteristics were found to be (weak) secondary predictors of accident frequency (U.S. Department of Transportation, 1981).

The relationship of accidents to the traffic volume product was strongest at those crossings with low traffic. Also, changes in the number of trains appears to have greater impact than change in the number of motor vehicles traversing a given crossing (U.S. Department of Transportation 1981).

Human behaviour is a significant and poorly understood factor contributing to the occurrence of collisions. FRA research also found that public awareness and reaction in the crossing situation is a function of such factors as car insulation level, radio/tape player volume, exhaust noise, alignment and sight lines, driver attention, driver fatigue, driver age and other driver environmental factors (U.S. Department of Transportation 1978).

As will be discussed elsewhere, drivers are not only profoundly ignorant about railway crossings and very inattentive; they also have a short memory. Advance warning signs placed too far from the crossing are actually forgotten before the crossing is reached. Warning assimilation takes 2-2.5 seconds and reaction takes another 1-1.5 seconds. At 60 mph this means a distance covered of 264 to 354 ft (U.S. Department of Transportation 1978).

There is also a substantial amount of indecision as the motorist approaches the crossing. The motorist may:

- increase speed;
- stop and then go;
- go and then panic stop;
- suffer a stall on the tracks; and
- fail to abandon a stalled vehicle.

In one notable case a woman whose car had stalled on the track abandoned the vehicle but then returned to close the door and was killed by the train.

A 1971 study of accident victims indicated that 66% of the respondents drove around closed gates or ignored lights, and the majority felt the alarm had come too soon or was false. This study also observed crossings in the Kingston, Ontario area during the summers of 1973 and 1974 using semi-concealed observation points. The following motorist behaviours were described:

- proceeding through crossing after signal onset, barely missed by descending gate;
- same as above but vehicle stuck by gate;
- skidding onto crossing and then backing through descending gate;
- passing tandem truck already stopped for crossing;
- inching forward onto tracks;
- waiting on switching track for train to pass on main line; and
- multiple incursions onto crossing surface with gates closed resulting in 'traffic jam' situation inside closed gates (Wilde et al 1975).

Part of the problem identified in the study was due to very long warning intervals (time from single onset until train arrival) which ranged from 30 to 120 sec. It was suggested that signals should reduce decisional uncertainty and be more credible in all circumstances. Otherwise drivers become accustomed to disobeying signals.

There are a number of obvious keys to improving driver performance and these include:

- education;

- safety training;
- licensing practices;
- law enforcement;
- attitude/behaviour modification;
- physiological capability improvement - motor training; and
- enhancing the negative reputation of dangerous crossings (Sanders 1976).

Appendix 2.2 General Evidence of Signal Effectiveness from the Literature

A number of studies in the U.S. and Europe have examined the effectiveness of protective devices in reducing accident frequency. There has only been one comprehensive analysis of protection in Canada (CTC 1985), however. This study, conducted for the CTC, reviewed the history of accidents and derived methods for ranking hazards and allocating funds. It did not derive empirical estimates of risk reduction attributable to the above upgrades.

At the request of the Rail Transport Committee, CTC's research branch conducted a study of possible means of ranking crossings for upgrade investment purposes. This study opens with the declaration that there is currently: "...no rigorous, systematic approach to decide on the degree and location of incremental improvement of grade crossing (signalling) protection" (CTC 1985).

Not only was there not a satisfactory method, there were also substantial data collection and analysis problems including: "...lack of authoritative, consistent and comparable data - particularly on important causative factors which are independent of the physical characteristics of level crossings, their protective devices, train volume and vehicular volume..." (CTC 1985). There are considerable factors of random human error, of impairment and even of spontaneous suicide on viewing the train.

Table 2-14 presents relative hazard indices for protection devices as cited in a number of U.S. sources. The relative hazard index is an indicator of the relative probability of the occurrence of an accident for different protective devices, all other conditions being equal. There is substantial evidence that there are incremental protective effects associated with the different devices studied.

In comparison, a 1985 CTC memorandum found that the average traffic volume product (rail-vehicle traffic cross-product) and accidents per million units of traffic volume product were as follows for the three protection types:

	AVERAGE TRAFFIC VOLUME PRODUCT	ACC/MILLION TRAFFIC VOLUME PRODUCT
Crossbuck	1,439	10.11
Flashing Light and Bells	15,734	2.53
Gate	86,092	0.18

Although these data are not standardized in terms of conditions other than traffic volume product, they do indicate a significant incremental effect of the protection devices under study.

Table 2-14: Relative Hazard Index of Protective Devices at Grade Crossings

Protective Device	Source		
	A	B	C
Crossbuck	1.00	1.00	1.00
Stop sign	-	0.58	-
Wigwag	0.63	0.34	-
Flashing Lights and Bells	0.33	0.20	0.35
Gate	0.13	0.11	0.16

Source: A Sanders et al., 1978
B Schopport and Hoyt, 1968
C Input Output Computer Services, 1981

Note: The relative hazard index indicates the relative probability of an accident at a crossing for different types of protective devices, all other conditions equal.

CASE STUDY NUMBER 3

ACCIDENT REDUCTION IN THE OIL AND GAS DRILLING INDUSTRY

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3. ACCIDENT REDUCTION IN THE OIL AND GAS DRILLING INDUSTRY

3.1 Introduction

This case study is concerned with efforts in Alberta to reduce accidents in the oil and gas drilling industry. Although the drilling industry has been active in the province for most of the twentieth century, it was not until the late 1970s that a conscious and concerted effort was made to reduce accidents. There are numerous sources for the causes of accidents including the use of complex machinery, the movement of large unwieldy materials, exposure to the elements and worker and management attitudes towards safety. Efforts to reduce occupational risk have concentrated on worker training and on creation of improved attitudes towards safety. This case study documents changes in occupational risk that have occurred on the drilling rigs and relates these changes to expenditures by individual drilling companies on safety activities.

3.1.1 Background and History: The Alberta Industry

The oil and gas drilling industry in Alberta has been an important component of the province's economy since the first major oil find was made in the Turner Valley area over 50 years ago. As a part of the larger oil and gas industry, it has contributed to the province's past prosperity. At its peak in 1980, the drilling and servicing industry created approximately 17,000 person-years of direct employment and generated additional work in the supporting service industries. In recent times, most of the drilling work is contracted to firms that specialize in this field, although some integrated oil companies are major owners of drilling companies or operate their own drilling divisions.

During the initial years of development, a laissez faire attitude dominated the oil and gas industry, subject as it was to a minimum of government regulations. For many years the image of the industry, and of drilling especially, has been one of tough work where the risks and the rewards are high. As well, employment on the rigs is seasonal and often located in remote areas of the province which encourages a transient workforce. Because the work is seasonal, it enables farmers and others to supplement their income. As a result, work on the rigs has been viewed as a normal and accepted part of life in many Alberta communities. However, the promise of high pay, readily available work and adventure, whether on the rig or during off-hours, created an image that has attracted many. Not unexpectedly, on-the-job safety considerations were not always a priority for management or drilling crews.

In the late 1970s, the industry was expanding rapidly and was unable to maintain past safety records. In 1979, for example, 22 fatalities occurred in the oil and gas drilling and servicing industry. Public concern and government pressure were brought to bear on the industry with the result that a number of safety measures were implemented to reduce occupational hazards.

3.1.2 Nature of the Hazard

The hazards of the drilling industry are almost always the consequences of accidents incurred while on the job site. The work entails the use of complex equipment in potentially dangerous situations (U.S. Dept. of Labor 1983). Typical on-the-job hazards include:

- exposure to powerful machinery used to hoist materials and to rotate the drillstem;
- unfavourable working conditions (outdoor environment, limited space, floors slippery from drilling mud);
- the movement of large, heavy materials;
- pumping fluids under high pressures;
- exposure to hazardous substances such as sulphur dioxide and acids;
- setting up and taking down derricks;
- working at heights with attendant risk of falls and the risk to workers of being struck by falling objects.

Statistics maintained by the Alberta Department of Occupational Health and Safety (OHS) provide some indication of the nature of the occupational hazards. The profile of the worker most likely to be injured is one who has been employed for less than one year, who is young and who works either as a roughneck or as a derrickman. In 1981, for example, 53 percent of all lost time claims were attributed to workers who had worked for six months or less with their current employer (OHS 1983). Data available on lost time statistics from other years show that 66 percent of all accidents in 1978 involved workers aged 24 years or younger. While this percentage declined to 53 percent for this group by 1984, this age group as a whole remained the group most at risk (M. Fromm, pers. comm.). Fatality statistics show that of the 32 fatalities that occurred in the drilling industry from 1976 to 1981, the occupations most often involved were roughnecks (15 fatalities) and derrickmen (12 fatalities).

Table 3-1 summarizes the accident types, the sources of the injuries and the nature of the injuries for lost time accidents in Alberta in 1984. The most common accidents types, which account for nearly 80 percent of the total lost time accidents, are classified as "struck by", "caught in, under or between", "overexertion", and "fall from an elevation". The balance of the table shows that the leading sources for the injury were from metal items, hoisting apparatus and working services while the leading types of injuries were contusions, fractures, sprains and multiple injuries.

A clearer profile of the source and nature of accidents on drilling rigs is obtained from other data sources. Specifically, the U.S. Department of Labour

Table 3-1: Lost Time Accident Claims for the Drilling Industry in Alberta, 1984

	PERCENT
(a) Accident Type	
struck by	31
caught in, under or between	25
overexertion	12
fall from elevation	9
fall on same level	7
bodily reaction	5
other	11
Total	100
 (b) Source of Injury	
metal items	28
hoisting apparatus	24
working surfaces	12
hand tools	7
bodily motion	5
other	24
Total	100
 (c) Nature of Injury	
contusion, crushing, bruise	22
fracture	21
sprain, strain	24
laceration, cut, puncture	9
multiple injuries	13
burns (thermal, caustic chemicals)	5
other	6
Total	100

Source: Alberta Occupational Health and Safety

(1983) carried out a survey of workers who were injured while working in the drilling and servicing industry. The survey presents a picture of drilling rig accidents that is similar to Alberta's. Further details of this survey are provided in Appendix 3.1.

3.1.3 Objectives and Scope

The objectives of this case study are to:

- (i) document the reduction in accident rates associated with drilling the oil and gas industry in Alberta;
- (ii) describe the types of activities that were undertaken by government and industry to reduce the risk of accidents in the industry;
- (iii) estimate the expenditures associated with activities that were undertaken to reduce accidents in the industry;
- (iv) derive an estimate of average expenditures per unit of reduced risk from accidents; and
- (v) describe the roles, responsibilities and rationales of the key actors involved in reducing accidents on drilling rigs.

The scope of this case study is focused on the efforts of the drilling industry to reduce on-site accidents associated with the drilling of oil and gas wells in Alberta. The Province of Alberta is chosen because it is the head office location for most of the drilling companies and because this province remains as the most active area in Canada for drilling activities. For example, it accounted for 83 percent of all active rigs in Canada in March, 1986 (CAODC 1986). Excluded from the study are accidents related to oil and gas well servicing.

The timeframe for the case study is from 1963 to 1985. While information on this period is presented, subsequent investigation of the data is concentrated on the 1977-1985 period when the most noticeable changes in accident rates can be observed.

Expenditures on risk reduction are identified and quantified for a sample of drilling companies. The quantified expenditures include primarily those budget items that can be directly attributed to safety programs of the responding companies; additional soft costs are incurred by the drilling contractors, but these can only be described in qualitative terms.

3.2 Methodology

3.2.1 Definition of Risk

Risk in this case study is defined as the number of accidents per million metres drilled measured on an annual basis (accidents as reported by the

drilling companies to the Alberta Workers' Compensation Board). This measure is hereafter referred to as the standardized annual accident rate. The accidents include both lost time and medical aid accidents. A separate accident is recorded for each worker injured, although several workers could have been injured in one event. Medical aid accidents are of a more minor nature where some medical assistance is given to the worker, but the worker is able to return to work the same day as the accident. An initial rate is derived by calculating the number of accidents per year per million metres drilled. This accident rate is then converted to a rate expressed in thousands of man-years worked.

3.2.2 Documentation of Risk Reduction

Accident data are obtained from the Annual Reports of the Workers' Compensation Board (WCB). The data are presented variously as "accidents reported", "number of claims reported", and "nature of injury in accidents reported". Although there have been some definitional changes in the data collected, this data set is the most complete available.

The number of metres drilled in a given year was used as an indicator of the level of activity in the industry. This data set was obtained from Oilweek magazine. Man-years worked is estimated by OHS from wage and payroll data reported by employers. Biases are believed to exist in the man-year estimates from one year to the next; accordingly, an average ratio of 0.7537 man-years worked per 1000 metres drilled is used to convert metres drilled to man-years worked. This average is drawn from the available OHS data. Risk reduction was measured as the difference in the standardized annual accident rate over the period of time from 1963 to 1985. (See Section 3.3.1).

3.2.3 Collection of Expenditure Data

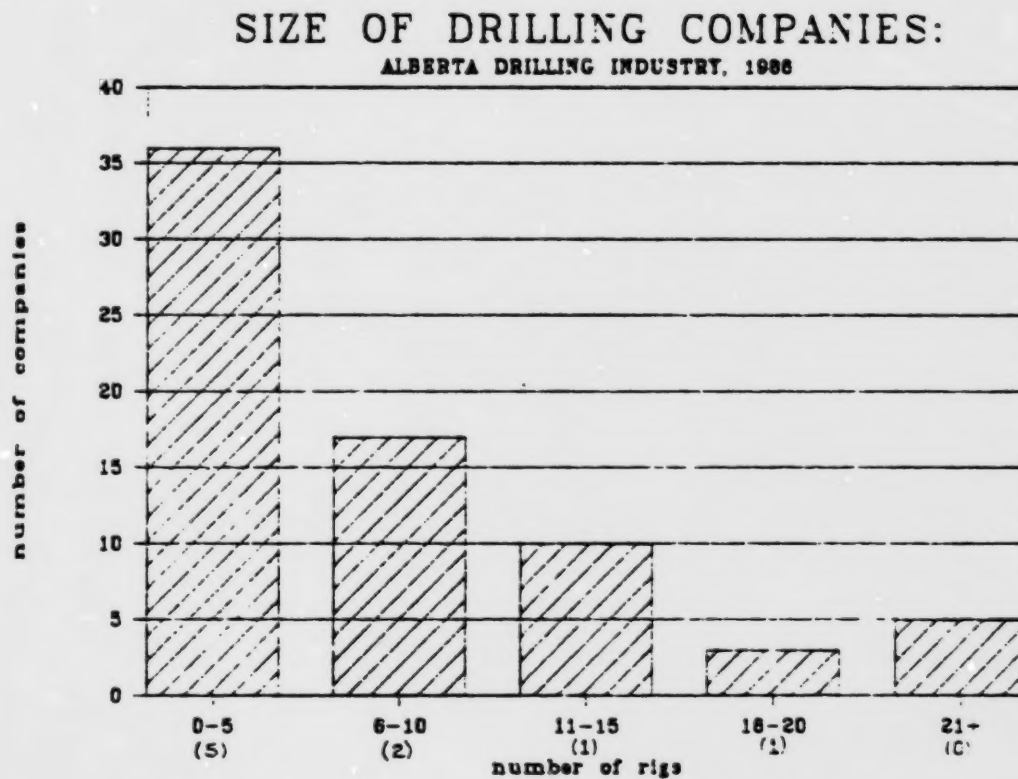
A survey of the oil and gas drilling industry was carried out to obtain expenditure data related to safety efforts. The survey entailed a mail-out questionnaire to all Alberta-based drilling companies. After a waiting period, companies that had not yet responded to the survey were telephoned to remind them to complete the form. Where responding companies agreed to participate, additional in-depth interviews were held to obtain more detailed information on measures taken to reduce occupational hazards. A total of 66 survey questionnaires were mailed out. Of these, nine completed questionnaires were returned and an additional seven interviews were conducted. The low response can be attributed to the severe economic crisis that many of the companies were in at the time of the survey.

The companies that chose to respond are broadly representative of the drilling industry as a whole. Table 3-2 presents some summary information on the responding companies. Most of these companies were relatively small, having on average seven rigs and a maximum employment of approximately 130 persons. The respondent companies were exclusively engaged in oil and gas drilling, although one operating company was a division of a major integrated oil company.

Table 3-2: Characteristics of Responding Drilling Companies

	AVERAGE	MINIMUM	MAXIMUM
No. of Rigs	7.1	2	18
Assets (\$ Million)	7.1	2.0	11.3
Metres Drilled in 1985	72 700	18 400	185 800
No. of Employees (Seasonal Peak)	127	32	282

Figure 3-1: Size of Drilling Companies



Note:

1. The number in parentheses indicates the number of firms participating in the study by size category.

Figure 3-1 relates the size of the respondent companies to the overall composition of the industry (CAODC 1985). The comparison is on the basis of number of rigs operated by each company. The bar graph represents the make-up of the industry while the bracketed numbers below each bar show the number of firms sampled from that size group. All groups of companies were sampled, except for the largest firms. As well, most of responding companies were drilling companies having five or fewer rigs, the largest group of firms within the industry. Finally, the sampled companies had an average of 7.1 rigs/company while the industry average was 8.3 rigs/company, indicating that a broadly representative sample of drilling firms was surveyed.

3.3 Results

3.3.1 Evidence of Risk Reduction from Alberta Drilling Accident Data

This section compares changes in industry activity to changes in the frequency of accidents over the 1963-1985 period. Because of the cyclical nature of the industry, some interpretation is required to establish that risk has been reduced. Two approaches are taken to estimate the reduction in risk. The first is to compare actual accident rates to the predicted rates that would have occurred if no efforts had been made to improve safety. The second approach compares accident rates before and after the introduction of safety measures.

Figure 3-2 displays the level of drilling activity that has taken place in Alberta from 1963 to 1985, as indicated by the millions of metres drilled each year. Also presented are the number of accidents that have occurred each year. The exhibit shows that from 1963 to 1971, drilling activity was roughly constant. From 1972, there was an upward, but erratic increase with a maximum being reached in 1980. During this period, year to year increases in activity typically ranged from 10-30 percent. With the introduction of the National Energy Program and a world surplus of oil and gas, drilling activity quickly tailed off to mid-1970 levels. However, the industry rebounded with a return to high levels of activity from 1983 on.

The number of accidents each year has generally paralleled the level of drilling activity. Inspection of Figure 3-2 reveals, however, that accident frequency increased more rapidly than drilling activity in the late 1970s and declined more rapidly after 1980. Accident levels in the 1983-1985 period approximate the experience of the early 1970s, even though drilling activity had much increased.

Since the industry made its major effort to improve drilling safety commencing around 1979-1980, it is instructive to compare activity and accident levels immediately before and after this time. Comparison of these two periods as shown in Table 3-3 indicates that they were similar in terms of volumes of work completed, but the number of accidents in the latter period was approximately half of the former.

Figure 3-2: Number of Accidents and Metres Drilled

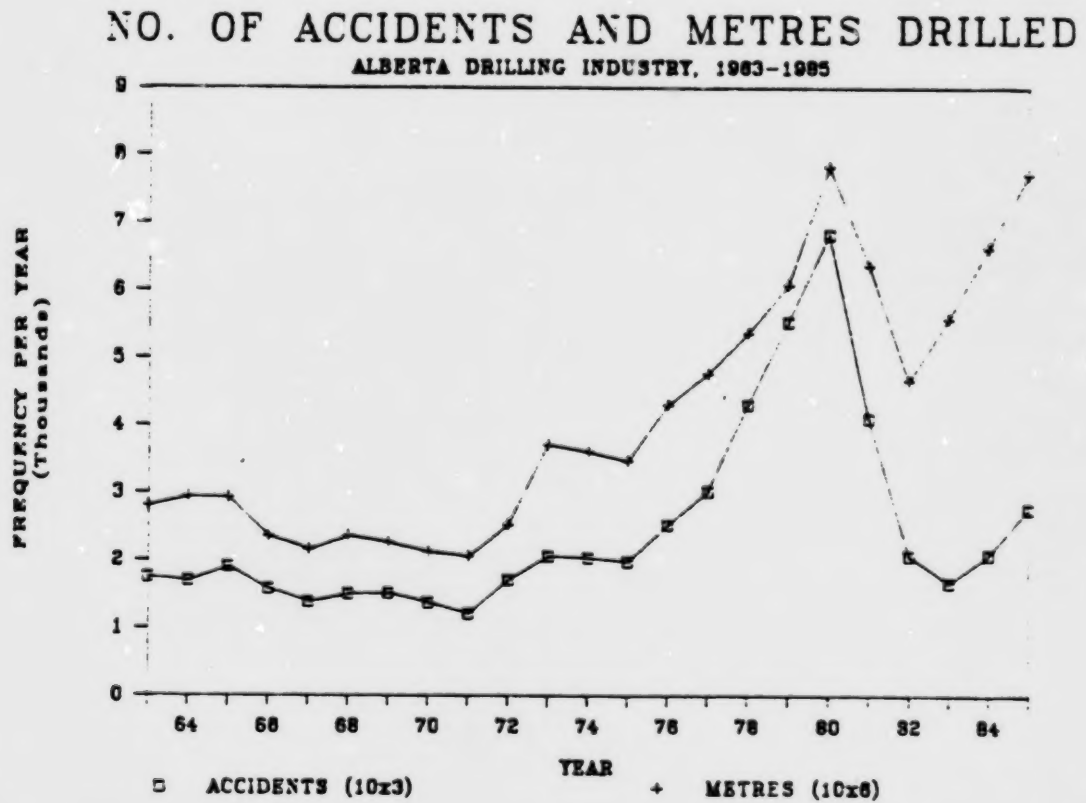


Table 3-3: Comparison of Drilling Activity and Frequency of Accidents,
1977-1979 and 1983-1985

	1977-1979	1983-1985
Wells Drilled		
Total over Period	14 834	16 177
Average per Annum	4 944	5 392
Metres Drilled ('000)		
Total over Period	18 873	19 952
Average per Annum	6 291	6 650
No. of Accidents		
Total over Period	12 862	6 532
Average per Annum	4 287	2 177

(a) Predicted Versus Actual Accident Rates

Figure 3-3 presents a scatterplot of drilling activity and number of accidents for the 1963-1985 period. The scatterplot shows a clear relationship between drilling activity and number of accidents from 1963 to 1980. Regression analysis was used to fit a line to this trend and a good linear relationship was found.¹

The number of accidents relative to drilling activity for 1983, 1984 and 1985 is clearly below the trend established for the 1963-1980 period. This lower incidence of accidents can be attributed to the cumulative efforts of the drilling industry and other actors to increase safety. There is some evidence of reduced risk for the years 1981 and 1982; however, the drilling industry as a whole was subject to considerable contraction of activities during this time and it is difficult to dissociate efforts to improve safety from other factors that could reduce the number of accidents. For example, it is likely that reduction in drilling activity resulted in the layoff of the least experienced workers, those most prone to accidents.

The impact of efforts to reduce drilling accidents can be calculated by comparing the actual number of accidents that occurred in 1983, 1984 and 1985 to the number of accidents that would have occurred if no steps had been taken to reduce accidents. The number of accidents in the "without safety efforts" case is predicted using the regression line described above. The results for the three years are as follows:

<u>Year</u>	<u>Actual Number of Accidents</u>	<u>Without Safety Efforts</u>	<u>Predicted Less Actual</u>
1983	1673	4393	2720
1984	2088	5387	3299
1985	2771	6427	3656
Total	6532	16207	9675

The total reduction in accidents over the three years was therefore 9675.

When standardized, the impact of the safety efforts on 1983-1985 drilling activity was to reduce the standardized annual accident rate by an average of 485 accidents per million metres drilled or 643 accidents per thousand man-years.

(b) Before/After Accident Rates

Figure 3-4 shows the overall changes in annual accident rates for the 1963-1985 period. Prior to 1977, accident rates averaged around 630 accidents per million metres drilled. After 1982, the average fell to 327 accidents per million metres drilled. The equivalent man-year rates are 836 accidents per

¹ R^2 value was 0.94 and the t-statistic was significant at 99 percent.

Figure 3-3: Accidents versus Metres Drilled

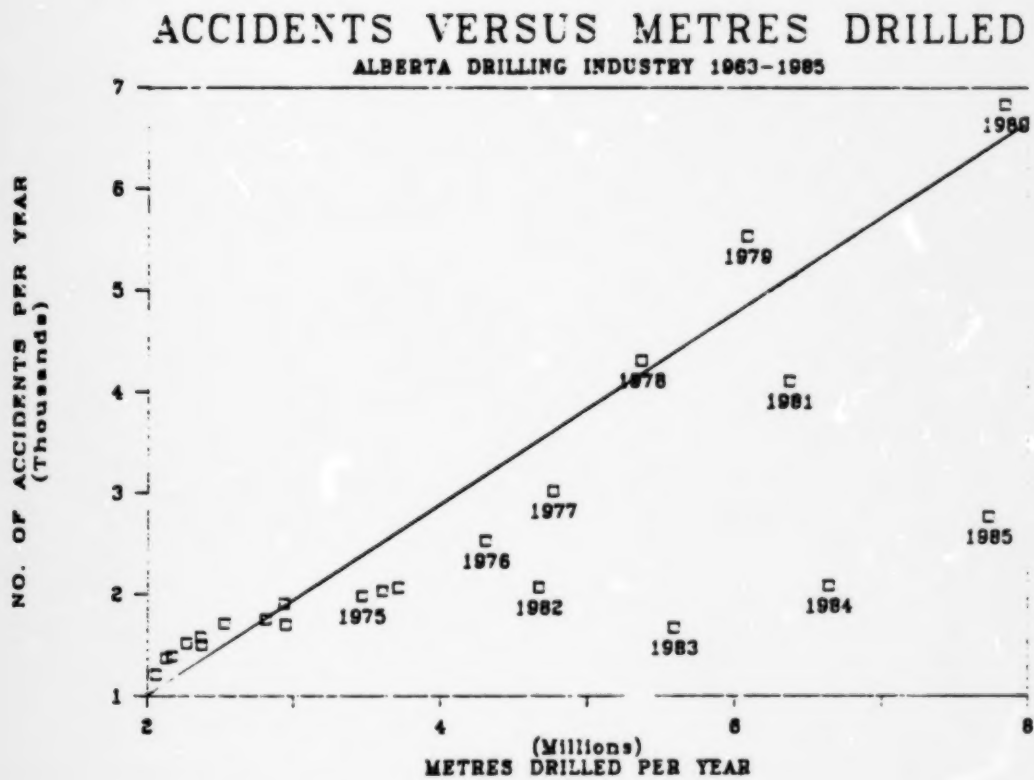
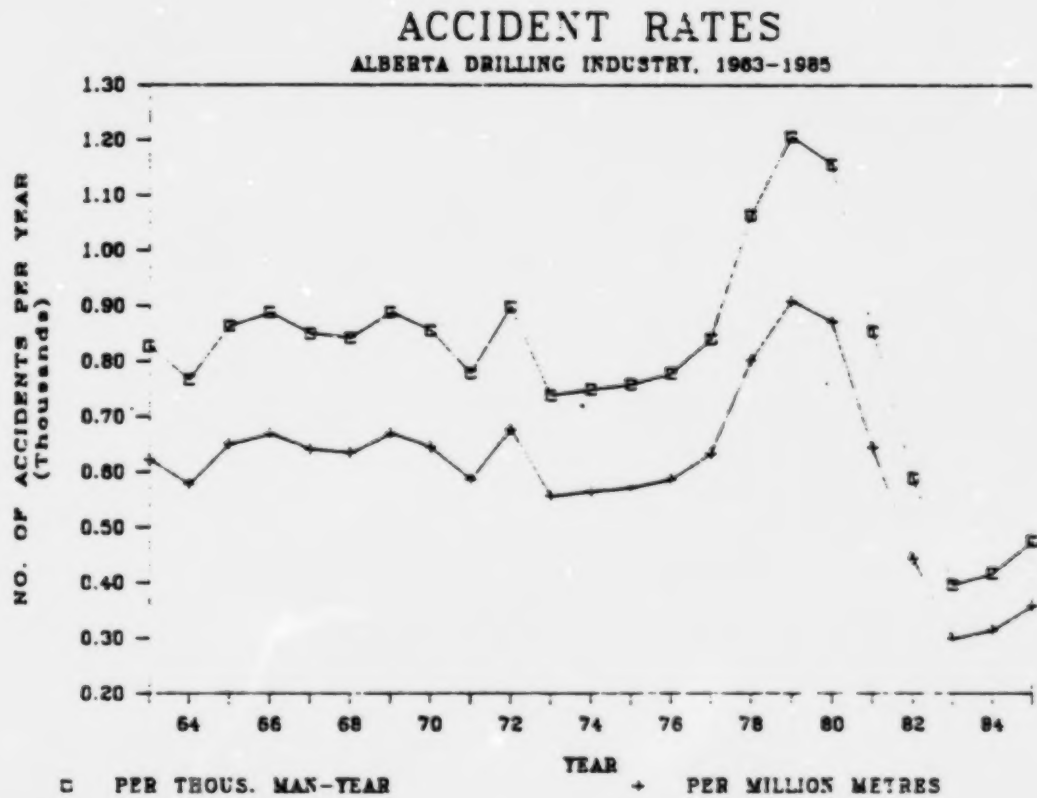


Figure 3-4: Accident Rates



thousand man-years prior to 1977 and 434 accidents per thousand man-years after 1982. The reduction in the standardized annual accident rate is therefore the difference between the before and after rates and is calculated to be 303 accidents per million metres drilled or 402 accidents per thousand man-years.

The following summarizes the results of the two methods used to estimate the average reduction in standardized annual accident rate for the 1983-1985 period.

	<u>Predicted vs. Actual</u>	<u>Before-After Comparison</u>
Accidents/million metres	485	303
Accidents/thousand man-years	643	402

The difference between these two estimates is large, given that it is equivalent to one-half of the actual 1983-1985 average accident rate. Part of the reason for the difference is that accidents from 1977-1980 were excluded in the Before/After Comparison. This period is when accident rates were rising rapidly. These years are excluded on the assumption that this period was an anomaly, subject to very rapid expansion both within the industry and generally in the western economy. Inclusion of these years' accident rates in the Predicted vs. Actual approach is based on the assumption that, prior to 1981, activity levels are the key determinant of accident rates. Available evidence does not allow a clear determination of one estimate over the other. Accordingly, the two estimates are presented as high and low estimates of accident reductions.

3.3.3 Expenditures on Risk Reduction

(a) Industry Expenditures for Accident Reduction

All respondents cited one or more of the following actions taken by their individual company as reasons for the decline in accident rates.

(i) Safety Management Program

A number of respondents stressed the importance of the industry in developing a positive attitude towards safety. It was only after 1979 that most of the respondent drilling companies starting putting together an explicit safety program to encourage and support safe operations. Components of a typical safety program are:

- a regular inspection schedule by senior company personnel;
- regular schedule for the reporting of accidents and safety meetings between the rig manager and senior management;

- an awards program tied to the number of days of safe operation. Depending on the company, profit sharing with rig managers can also be a part of the award;
- regular safety meetings with rig crews where accidents or near misses are discussed, the use of a piece of equipment reviewed, etc.;
- the retention of a safety manager as a regular employee.

(ii) Training

Senior on-site crew members are required to have training in blowout prevention control, boiler operations and first aid. Other crew members now typically receive an orientation training when they first start working and some crews will receive first aid training. Also, pre-employment training is available at the Petroleum Industry Training Service (PITS) and on-the-job training is enhanced through the use of videotapes. Available training packages provide information on specific work skills, opportunities for practice, and stress the importance of taking a safe attitude towards work, including discussions of alcohol and drugs, the importance of proper rest, equipment use and maintenance, H₂S, etc.

(iii) Equipment and Maintenance

Most respondents reported that there had been some improvements in equipment that was felt to contribute to a reduction in accidents. The equipment that was mentioned included blowout prevention devices, the use of power tongs instead of chains to make a joint, more powerful engines, improved electrical outlets, and better communications between head office and the rig manager.

Data on expenditures have been assembled on estimated annual direct expenditures (post-1979) by the respondent drilling companies. Table 3-4 presents these expenditures for each of the respondent companies. Relative to asset value of each company, which range in the millions, these expenditures appear to be relatively modest with annual expenditures averaging approximately \$70,000. Average annual expenditures per million metres drilled were \$969,000. As an inspection of the table shows, there is considerable variation in expenditures when companies are compared on a ratio basis.

The identified expenditures generally include the salary of the safety supervisor or consultant, purchase of training materials, training subsidies to workers while attending courses, and awards given to workers who have achieved safety targets. The expenditure estimates are understated because they do not include the time spent by the company to conduct inspections, prepare reports, ongoing training that takes place while the trainee is on the job and, generally, any time spent by senior personnel on safety related issues. Also, some respondents reported upgrading the equipment on their

Exhibit 3-4: Average Annual Expenditures on Safety Programs by Responding Companies¹

CASE NO.*	AVERAGE EXPENDITURES/ RIG (\$)	AVERAGE EXPENDITURES/ 1000 M DRILLED (\$)	AVERAGE EXPENDITURES/ EMPLOYEE (\$)
2	9 200	n.a. ²	\$ 500
3	2 700	430	115
4	5 000	480	222
5	15 000	1500	810
6	25 000	n.a.	156
7	11 300	1090	720
8	5 000	420	310
9	8 700	1090	610
WEIGHTED AVERAGE ³	\$ 9 700	\$ 969	\$ 565

* Case 1 excluded from analysis because involved in marine drilling.

Notes: 1. Expenditures are estimated averages of annual expenditures, for data provided for the post-1979 period. Dollars are then-year, as spent.

2. n.a. indicates data not available.

3. Weighting variables are number of rigs, drilled depth and number of employees per firm, respectively for each column of data.

rigs, but these expenditures were generally considered inseparable from general maintenance requirements. Finally, start-up costs of instituting a safety program were generally reported to be minimal.

(b) Expenditures for Accident Reduction by Other Organizations

Only partial information is available on expenditures made by the other actors. The following are noteworthy for their magnitude:

- Expenditures of the Petroleum Industry Training Service on drilling industry related training programs amounted to approximately \$5.2 million for the 1980-1985 period. This expenditure cannot be considered additional to expenditures by the drilling companies, however, since PITS is supported by drilling company contributions. Moreover, total incremental increase in expenditures from 1982 to 1985 over the 1980-81 year is less than \$1 million, indicating a small net increase over previous years' efforts in formal training.
- Inspections of drill rigs conducted by the Alberta Energy Resources Conservation Board (ERCB) require approximately 2800 person-days of effort each year (ERCB 1984).
- Efforts of the Canadian Association of Oilwell Drilling Contractors (CAODC) require large amounts of volunteer time on the part of the association members.

3.3.4 Expenditures per Unit of Risk Reduction

This section brings together findings on the reduction in accidents, which were obtained from industry-wide data, and expenditure data, which was obtained from a sample of drilling companies. To review, the reduction in the standardized annual accident rate was estimated to range between 303 accidents and 485 accidents per million metres drilled. Average annual expenditures on safety efforts were estimated at \$969,000 per million metres drilled. Therefore, the unit cost of reducing accidents is estimated to fall between \$2000 and \$3200 per million metres drilled for one unit reduction in the standardized annual accident rate.

It should be noted that this estimate is likely an understatement of true costs because:

1. It does not include the cumulative expenditures by industry from one year to the next;
2. Expenditure estimates do not include soft costs incurred by the drilling industry nor increased governmental expenditures.

3.4 Discussion

3.4.1 Reliability of Estimates

It is evident that the rate of accidents on drilling rigs has fallen significantly in recent years compared to the long-term average. Also, the industry, stimulated by government, has made considerable efforts to improve rig safety. Most informed individuals generally attributed improved rig safety to these efforts.

It is possible that the reduction in risk can be attributed in part to other factors, specifically to a shift in the makeup of the workforce to an older, more mature worker. In the late 1970s, the western Canadian economy was expanding at a rapid rate and placing heavy demands on the labour market. Many industries had difficulties in recruiting skilled and reliable personnel. As a consequence, an increasing proportion of unskilled and untrained employees were added to company payrolls. The effect of the tight labour market on rig safety was generally recognized by the drilling industry. It was reported that drilling contractors were unable to draw from a pool of qualified applicants, that hired applicants were difficult to retain, and that normal selection procedures were often by-passed as employers struggled to maintain full drilling crew complements (OHS 1979).

Since the economic downturn of the early 1980s, there has been a chronic surplus of labour on the Alberta job market. Because of the oversupply it is likely that drilling contractors have been able to increase the proportion of employees on the rig who are seasoned employees. One possible indication of this is the rapid decrease in lost time accidents involving workers aged 15 to 19 years of age. In 1978, this group accounted for 31 percent of all lost time accidents. By 1984, its share had declined to 9 percent of the total. Conclusions that can be drawn from this data are limited, however, since age-specific accident rates are not available. Nevertheless, it has been generally observed that older workers tend to have lower accident rates (U.S. Dept. of Labor, 1983). Thus, the drilling industry could be improving its accident rate in part by simply hiring an older more mature worker. This approach to reducing accidents would be made easier by the slack labour market prevalent in Western Canada in the 1980's.

3.4.2 Roles, Responsibilities and Rationales for Risk Reduction

(a) Roles and Responsibilities

Efforts to improve safety on rigs have involved five main groups of actors:

- Alberta Occupational Health and Safety Division (OHS);
- Individual drilling companies and their representative industry association, the Canadian Association of Oilwell Drilling Contractors (CAODC);

- Petroleum Industry Training Service (PITS);
- Energy Resources Conservation Board (ERCB);
- Individual operating companies that contract with the drilling companies.

Government regulatory efforts have been focussed through OHS, a division of the Alberta Department of Workers' Health, Safety and Compensation. OHS is responsible for enforcing the statutes and regulations of the Occupational Health and Safety Act. The individual drilling companies, through CAODC, have developed and implemented many safety measures. A basic approach of CAODC has been that most accidents can be prevented through safety training and development of proper attitudes towards safety. An important actor in safety training is PITS, which provides both mandatory and optional training for the drilling industry.

The ERCB's mandate regarding rig operations is to ensure that rigs can maintain control of wells under all situations, particularly to avoid blowouts. To achieve this, the ERCB has established a set of regulations that has generally encouraged better maintained equipment and more careful management. The operating companies have also had an indirect effect in encouraging the safe operation of rigs because of their preference to contract with drilling companies that have a good safety record.

The drilling industry and the government regulatory agencies tend to cooperate on health and safety issues. While both OHS and the ERCB are responsible for ensuring that the drilling companies adhere to the established regulations, these two agencies have instituted joint government-industry committees to develop new safety measures and to advise in the preparation of regulations (OHS 1985). The commencement of the cooperative approach occurred with the establishment of a task force in 1979. It was formed in response to a large number of fatal accidents in the industry in that same year. Since then, the Lodgepole blowout in 1982 stimulated additional intensive consultations between industry and government (Oilweek, 1984). The blowout was out of control for some 68 days during which large volumes of sulphur dioxide were released and several fatalities resulted. The cooperative approach to safety is supported by the CAODC which prefers the industry to be self-regulating as much as possible.

Regulatory authority comes from two principal Alberta statutes: the "Occupational Health and Safety Act" administered by OHS and the "Oil and Gas Conservation Act" administered by the ERCB. The statutes and associated regulations for both of these acts have been substantially revised since 1979.

(1) Occupational Health and Safety

OHS undertakes safety inspections to see that its regulations are enforced. In addition to the general regulations found in the Act, there are over 20 specific regulations specific to the drilling industry. A

total of 475 inspections were carried out by OHS in 1984, amounting to approximately 2 percent of all safety inspections conducted by the department. As well, it gives courses and seminars and prepares information reports on recent accidents and how they might have been avoided.

(11) The Energy Resources Conservation Board

The ERCB carries out a substantial inspection program. In 1984, for example, over 2000 inspections were conducted. The Board does not inspect all drilling rigs, but rather concentrates its efforts on those rigs where the risk of an accident is greater (Drilling Rig Inspection Committee 1984). Priority is given to inspecting those rigs having a poor safety record, starting up winter operations, drilling deep wells; or for rigs located in potential sour gas areas or in environmentally sensitive areas.

In addition to inspections, the ERCB regulations require the drilling contractor to make substantial provision for safety equipment to prevent and control blowouts. Other requirements include the certification of key staff in blowout prevention, training of the drilling crews, weekly blowout prevention drills, and regular inspection and testing of equipment. Although the Oil and Gas Conservation Act makes provision for the "safe and efficient" drilling of wells, the mandate of the ERCB is generally interpreted as "to effect the conservation of, and to prevent the waste of, the oil and gas resources of Alberta" (Alberta 1980). Consequently, most of the effort of the Board has been to prevent blowouts and the resultant loss of resources.

(111) The Workers' Compensation Board

The WCB plays the key role in monitoring accident levels and in setting the assessment rates for each industry. The WCB will levy a surcharge of one-third of the normal assessment on companies that have an above average rate of lost time accidents; companies with good accident rates receive rebates of one-third of the normal assessment. This system was considered by survey respondents to provide an incentive to the industry to improve worker safety.

(iv) Canadian Association of Oilwell Drilling Contractors

The drilling industry is represented by the CAODC. Between 1978 and 1979, the CAODC formed the Accident Prevention Committee. Each month this committee reviews recent accidents and makes recommendations to prevent similar accidents in the future. Reports presenting this information are sent to all drilling contractors. The committee is also responsible for annual safety awards and the awards banquet. In addition to these ongoing activities, CAODC works on a number of ad-hoc projects. For example, a modular training package for all positions on a drilling

crew was assembled by the CAODC. Portions of this package are now adopted by individual drilling companies for use in their own training programs.

(v) Petroleum Industry Training Service

PITS provides training of drilling industry workers in mandatory certification programs as well as in optional programs (PITS n.d). PITS was established in 1949 and has since undergone a number of organizational changes. It is now managed by a board of directors drawn from oil industry associations and from members at-large and is fully financed by course fees.

Courses are developed through steering committees that include representation from industry and government. It can be an intensive effort: the H₂S alert course required 1.5 years to assemble and to secure the steering committee's unanimous approval. Although a number of the courses are concerned primarily with teaching proper work procedures, the opinion of PITS is that attitudes towards safety comprise an important component of the courses and that their training programs help develop safer on-rig operations (Anderson, pers. comm.). PITS has provided approximately 44,500 student days of training from 1981 to June, 1985 and has had an average enrollment of close to 2000 students each year.

(vi) Individual Companies

Efforts to reduce risk on the drilling rigs typically involve four different employee positions (CAODC n.d.): the senior executive in charge of drilling (the company president or division vice-president); the safety manager or his designate; the rig manager; and the drilling crew. Some smaller companies may retain a safety consultant instead of having a safety supervisor on staff. Respective responsibilities can be summarized as follows:

President/Vice-President:

- authorizes final decisions on expenditures for safety items;
- involved in identifying safety problems and solutions, especially where the company is smaller.

Safety Manager:

- involved in day-to-day management of safety issues;
- inspects rigs on a regular basis;
- reviews safety reports and minutes of safety committee meetings;

- identifies problems and develops solutions with rig managers.

Rig Manager:

- responsible for on-site safety and safety training;
- resolves, where possible, safety problems as they arise;
- carries out weekly inspections and safety drills;
- prepares regular reports and maintains logs related to government safety regulations and internal company requirements;
- chairs safety meetings.

Rig Crew:

- some involvement in inspections;
- participates in weekly safety meetings at the drill site;
- senior crew train new staff.

(b) Rationale for Safety Expenditures

Most of the drilling industry respondents cited outside pressures on their companies as the initial reason why their company implemented a safety program. Inspections by OHS and the ERCB were both mentioned as important factors. These two agencies can issue a stop work order. The cost of having to cease work could be \$5000 to \$6000 a day for a 2000 to 3000 m well which can impose a considerable economic penalty. Additional factors cited include:

- unfavourable media coverage during the late 1970s on the high number of accidents and on the Lodgepole blowout;
- rebates paid by the Workers' Compensation Board to companies having below average accident rates;
- preferences of the major integrated oil companies to hire only those drilling companies with good safety records.

In general, anecdotal comments from the respondents and other informed individuals indicate that they consider change of attitude of the senior management one of the most important aspects of the safety program.

The respondents generally relied on the broad industry consensus in designing their safety program and in evaluating the effectiveness of their programs. Safety has been regarded by most actors in the industry as being a human resources problem where the solutions are seen in terms of motivation, training and monitoring. Consequently, more radical approaches such as

redesigning the rigs to be more mechanized do not appear to have been actively considered by the industry. Similarly, respondents tend to evaluate their own performance in the light of the industry standard as obtained from OHS statistics and safety consultants' comments. An explicit cost-effectiveness analysis of alternative safety measures does not seem to occur at the individual company level. A typical comment by respondents was that if something has to be done to improve safety, that it is done.

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Appendix 3.1 Further Information on Occupational Hazards of the Drilling Industry

Hazards are initially present during rigging up when the derrick and the associated machinery is assembled prior to commencing a new hole. Rigging up entails transporting the equipment to the new site, raising the mast, which can be up to 60 metres in length, and installing the various hoisting, pumping and electrical systems. Much of this machinery is large and complex. For example, the larger rigs may have three to four engines each capable of generating 2200 kilowatts of power or more.

Drilling is accomplished by means of a rotary table which turns the drill pipe and attached drill bit. During drilling, mud (drilling fluid) is pumped down the pipe through the drill bit to remove cuttings and to keep underground pressures under control.

As the hole becomes deeper, additional lengths of pipe are added to lengthen the drill string. Each length of pipe or joint is approximately 9 metres long. Adding a new joint or making up the drill stem involves manoeuvring the new joint onto pipe already in the hole and spinning the joint on tight to the drill stem. Periodically, the whole drill stem will have to be removed (tripping out) to replace a drill bit or to run tests. To do so requires breaking out the pipe to stands of pipe - usually three joints to a stand - which are racked in the derrick.

This description, although greatly simplified from actual practice, provides some basis for understanding the sources of injuries that occur on a rig (see Baker 1980 for additional detail). Rigging up and rigging down involves the hoisting or assembly of large, heavy pieces of machinery and structural equipment. During this time, crews are engaged in non-routine tasks. Making up and breaking out drill stems require the hoisting, manoeuvring and joining of long lengths of heavy pipe. Although this task can be made easier by the use of powered equipment, the roughnecks are required to use brute strength in many instances, particularly in positioning the pipe. They may have to work in close with equipment, especially with chains and power tongs. The risks from these types of jobs commonly involve strains from overexertion and injury to limbs from getting caught in the equipment. As well, the making up and breaking out of pipe is done with extreme forces with the attendant risks of equipment failure. While carrying out these tasks, the crew is located above the ground either on the drill floor or higher up on the derrick where falls are possible. Finally, drilling mud is circulated under pressure with the risks of blown valves and hoses. When tripping out, the risk of a blowout is increased. These hazards are compounded by the difficulties of working outdoors and the human problems of the attitudes of crew and management and high labour turnover.

Table 3-5 shows the rig activities that were taking place at the time of the injury (from a survey conducted by the U.S. Department of Labour). A significant percent of accidents occurred while tripping in or out or when a

joint was being added. These are activities that entail the use of hoisting apparatus, power tongs and movement of pipes and other heavy drilling material. Additional information showed that some of the injuries were the conclusion of a series of unexpected or unusual events. The end result was often the worker falling on a structural surface.

Contributing reasons for the accidents were also uncovered by the survey. Of the injured workers, less than half regularly performed the activity which resulted in the accident while close to 30 percent were performing the activity for the first time or performed it once a month or less. In general, this indicates a low degree of familiarity with the activity that resulted in the accident. Workers, when asked to identify contributing causes of the accidents, reported that they were "in a hurry" (28 percent of respondents), it was a result of "co-worker activity" (21 percent), or they were "not aware of hazardous conditions" (15 percent). These contributing factors underline the potential in the drilling industry for reduction of accidents through better safety training.

Table 3-5: Survey of Injured Oil and Gas Drilling Workers Activity at Time of Injury

ACTIVITY	PERCENT*
Tripping in or out	32
Adding a joint	12
Rigging up or down	11
Repairing, cleaning or servicing equipment, materials or rig structure	9
Repairing or servicing pumps, engines, generators or other motors	8
Materials handling	7
Working with drilling fluids	5
Other	16
Total	100

* n = 693 injured workers

Source: U.S. Department of Labour, 1983.

CASE STUDY NUMBER 4

REDUCTION OF OCCUPATIONAL EXPOSURE TO LEAD

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4. REDUCTION OF OCCUPATIONAL EXPOSURE TO LEAD

4.1 Introduction

This study examines the reduction of exposure to lead in workplace environments in the province of Ontario. Lead is one of the oldest recognized occupational hazards, having been used in industrial processes for hundreds, if not thousands, of years. In Ontario lead is both produced and used by a large number of firms involved in smelting, refining, metal fabrication and the manufacture of a wide array of products incorporating lead. This case study focusses on measures adopted by such firms to reduce the exposure of workers to lead and lead compounds and on the activities of government with respect to the regulation of occupational exposure to lead.

4.1.1 Background and History: Regulation of Lead in Ontario

The Occupational Health and Safety Act became law in October 1979. It did not contain regulations controlling the use in the workplace of specific toxic substances, however it contained provisions for regulation and control of specific substances through the Designated Substance program.

Lead was the first of many substances to be regulated under the Designated Substances program. In August of 1981, the Regulation respecting Lead, Ontario Regulation 536/81, made under the Occupational Health and Safety Act, was filed and came into force. While other substances have since been designated, and existing regulations have undergone some changes, the regulations restricting and controlling lead in the workplace have remained essentially the same since that time.

The lead regulation specifies maximum allowable airborne concentrations of lead and maximum allowable periods of worker exposure to those concentrations. The regulation specifies a requirement for a hazard assessment and stipulated provisions for a control program should a hazard be demonstrated. Furthermore the regulation establishes codes of practice for measurement of airborne lead, medical surveillance of workers, and the use of respiratory protective equipment. As part of the medical surveillance program, clinical tests of blood lead concentration are typically required. A concentration greater than 0.60 mg/L of lead in the blood requires an inquiry regarding work practices and personal hygiene. When the blood level concentration of a worker is found to exceed 0.70 mg/L a further test must be taken immediately and, if the result is confirmed, the worker removed from lead exposure. Special provisions are made for women capable of bearing children.

Although this study focuses on the period immediately prior to and after introduction of the lead regulations, it is apparent that many industry sectors and individual firms have been active in mitigating lead exposure for many years prior to the regulation. The regulation however provides a unique point in time which marks a broader and more comprehensive awareness of the hazards

of lead. Further details on the process by which the lead regulation came into effect are provided in Appendix 4.1.

4.1.2 Nature of the Hazard

Lead exposure in the workplace is today, and has been for centuries, recognized as a health hazard. Lead is commonly used in industry in a number of forms, and the exposure of a worker to lead may come about in a variety of ways.

(a) Health Effects of Lead Exposure

The following overview of the health effects of overexposure to lead is extracted from "Designated Substances in the Workplace: A Guide to the Lead Regulation" published by the Occupational Health and Safety Division of the Ontario Ministry of Labour (Ontario Ministry of Labour 1985). A substantial amount of toxicological and epidemiological research has been conducted on the effects of occupational and environmental exposure to lead. The interested reader is referred to the Report on the Designation of Lead in Ontario (Ontario Ministry of Labour 1981) for further details and an introduction to the literature. It is also noted that the Royal Society of Canada is currently conducting an extensive review of the effects of environmental exposure to lead and that previous studies have been conducted by the Robertson Committee (Ontario Ministry of Health 1974) and the Science Council of Canada (Science Council of Canada 1977).

"Overexposure to lead can affect:

(i) **The Blood:** Lead can interfere with the body's ability to manufacture hemoglobin, the molecule in red blood cells responsible for carrying oxygen to the tissues.

(ii) **The Kidneys:** Lead can reduce the ability of the kidneys to filter wastes from the bloodstream.

(iii) **The Gastro-intestinal System:** Lead poisoning may result in complaints of abdominal pain, loss of appetite, vomiting, nausea, constipation or diarrhea.

(iv) **The Nervous System:** Lead can cause peripheral nerve damage that results in muscle weakness. It may also lead to behavioural changes and to impairment of vision and hearing. At very high levels, lead can affect the brain, causing convulsions, coma, and even death.

(v) **The Reproductive System:** Lead may harm the developing fetus and may cause impaired sperm production.

Like many other poisons, lead may be harmful following a high dose received in a short period of time (acute poisoning), or after long-term exposure to lower doses (chronic poisoning).

Symptoms of acute lead poisoning include a metallic taste in the mouth and gastro-intestinal symptoms such as vomiting, abdominal cramps, constipation or diarrhea. The major effect of acute organic poisoning by either TEL (tetraethyl lead) and TML (tetramethyl lead) is on the central nervous system, with symptoms such as disturbed sleep, headache and psychosis.

The earliest signs of chronic lead poisoning may not be noticed because they are similar to many common complaints. These include headaches, fatigue, irritability, pains in joints and muscles, abdominal pain and constipation. More severe chronic poisoning leads to several characteristic symptoms, including a blue line on the gums, wrist drop (the inability to hold the hand extended), severe abdominal pain and pallor."

Whereas the effects of acute lead poisoning are relatively well understood, the effects of long-term exposure are only beginning to be understood as evidence accrues from long-term health, monitoring and epidemiological analysis. In an addendum to a paper prepared by the Ontario Ministry of Labour on the health effects of lead (Ontario Ministry of Labour 1981) it is noted that "some research suggests that chronic impairment of various kinds (neurological, psychological, renal) occurs in workers whose blood lead level according to exposure records never exceeded 0.7 mg/L. This type of research is receiving particularly careful attention".

Clinical lead poisoning is now a relatively rare occupational health problem. Between 1931 and 1940 an average of four deaths due to occupational lead poisoning occurred per annum in Ontario. After 1940 the death rate dropped dramatically and since 1960 there have been no reported deaths in Ontario due to lead poisoning. Between 1965 and 1978 a total of 292 claims related to lead exposure were awarded by the Ontario Workmen's Compensation Board. The number of claims per annum rose between 1972 and 1978 but it is suggested that this is a result of greater awareness of workers and industry of the hazards and effects of lead (Ontario Ministry of Labour 1981). Currently attention is focused on the more subtle effects of chronic low-level lead exposure on human behaviour, neurological systems and reproductive systems.

(b) Sources of Occupational Lead Exposure

There are three basic forms of lead. Metallic, or elemental lead is used to manufacture electric storage batteries, lead solder, ammunition, pipes, electric cable sheaths, and in the curing of some rubber products. It is sometimes combined with other metals to form a variety of alloys. Organic lead compounds contain a lead atom bonded to carbon in some organic molecule. Tetraethyl lead and tetramethyl lead are the most commonly known organic lead compounds, and are used as anti-knock agents in leaded gasoline. Inorganic

lead compounds contain a lead atom bonded to elements other than carbon. These compounds (such as lead oxides, lead chromate and lead nitrate) may occur as solids or liquids, and are used in pigments, paints, insecticides, glass, plastics and rubber compounds and electric storage batteries.

Forms of lead which create a hazard to workers are those which might be inhaled, ingested or absorbed through the skin. These are dusts, fumes, mists, vapours and some liquids. Dust is a common hazard as it is produced in so many ways. Whenever a powdered form of lead is used or manufactured, as in lead-acid battery manufacture (lead oxide) or lead based pigment use and manufacture (lead chromate and lead sulphate), the potential for exposure is high. Other processes such as cutting, sanding, grinding, crushing or simple handling may also create dust hazards.

Industries in which lead dusts are a significant source of hazard are mining and milling of lead ores; secondary smelters, where large volumes of lead are handled, and lead oxide may be manufactured; the electric storage battery manufacturers who may either manufacture their own lead oxide, or purchase it, and in either case, any manual transfer or handling of the powdered oxide presents a hazard; lead-based pigment manufacture, where both the raw materials (lead oxide) and finished product are in powdered form; lead based paint manufacture, where lead pigment is used; and in some metal fabrication industries, where sanding or polishing may be required.

Lead fume is produced when lead-containing substances are processed at greater than 500°C. The fume is created when lead vapour is released in a high temperature process. The vapour condenses to form a fume, or solid particles invisible to the naked eye which can remain suspended for long periods of time.

Processes and industries in which fumes form a significant hazard are primary lead smelting; lead recycling or secondary smelting; high temperature lead soldering; lead casting in any industry; manufacture of TEL and TML; manufacture of lead oxide (by the Barton process); lead alloying; and rubber production (where lead curing is practiced).

Lead-containing mists consist of suspended liquid droplets. They are produced in processes involving spraying, bubbling, or boiling of lead-containing liquids. The spraying of lead-based paints and primers is a significant source of such mists.

Hazards associated with vapours or direct liquid contact result primarily from organic lead compounds. They are more easily absorbed through the skin and may have a high volatility. Liquids such as TEL and TML present hazards in both ways. Exposure may occur at any point of production or use of these liquids.

The variety of forms of lead which may be encountered in the workplace, and the variety of the industrial processes which may produce them are indicators

of the complexity of the lead exposure problem. Many industries must utilize more than one of the above processes in the manufacturing of a product, and even within a particular industry, different firms may arrive at the same end through a variety of means. The complexity of the lead and lead product utilizing and manufacturing industries demands control measures which are tailored to each individual plant site or work area. Available control measures are discussed in Appendix 4.2.

4.1.3 Objectives and Scope

The objectives of this case study are to:

- (i) document the reduction in health risk associated with reduction in occupational exposure to lead in Ontario;
- (ii) identify and describe the ways and means by which occupational exposure to lead has been reduced in Ontario;
- (iii) estimate expenditures associated with measures implemented by industry and government in Ontario for the purposes of reducing occupational exposure to lead;
- (iv) derive an estimate of average expenditures per unit of risk reduction; and
- (v) describe the roles, responsibilities and rationales of industry, government and the worker with regard to decision-making on risk management.

The case study is limited to:

- (i) industrial uses of lead or lead compounds;
- (ii) industries located in the Province of Ontario;
- (iii) the time period of 1976 to 1985; and
- (iv) occupational exposure to lead only (i.e. excluding environmental emissions or substances to which the general public is exposed).

4.2 Methodology

4.2.1 Definition of Risk

For the purposes of this case study risk is defined as the annual group average probability of a worker in a lead regulated industry having a blood lead concentration in excess of 0.70 mg lead per litre of blood (0.70 mg/L); this concentration is the stipulated action level which a worker must be removed from lead exposure.

Operationally we have defined this risk as being the number of blood samples exceeding 0.70 mg/L blood lead concentration per year per 1000 samples analysed. We have assumed that there is an acceptable correspondence between

blood samples and the worker population such that "employee" can be substituted in this definition as follows: the number of employees whose blood lead concentration exceeds 0.70 mg/L per year per 1000 employees with exposure to lead.

4.2.2 Documentation of Risk Reduction

The results of six years of blood level concentration analyses conducted by the Occupational Health Laboratory of the Ontario Ministry of Labour have been reported by Walkinshaw (1985).

The Laboratory has analyzed some 68,000 blood lead specimens obtained from lead producing and using companies in Ontario between 1979 and 1984. As this period of time encompasses the introduction of the lead regulation in 1981, these data have been scrutinized for evidence of reduced blood lead concentrations.

The following extract from a paper prepared by the Laboratory (Walkinshaw, 1985) best describes the methods employed and results of the blood lead survey.

"The blood test results generated by the survey were categorized into the following five levels:

1.4	mol Pb/L	less than or equal to 0.29 mg Pb/L
1.5-1.9	mol Pb/L	0.30 - 0.39 mg Pb/L
2.0-2.4	mol Pb/L	0.40 - 0.49 mg Pb/L
2.5-3.3	mol Pb/L	0.50 - 0.69 mg Pb/L
3.4	mol Pb/L	greater than or equal to 0.70 mg Pb/L

The companies from which the blood lead specimens were obtained were divided into two types, core and non-core. A core company was defined as one that had submitted at least one sample for each of the five years from 1980 to 1984. A non-core company merely had to have submitted one sample for any of the five years. This division into company types was necessary to determine if trends displayed by all the companies reflected a true change in blood lead levels or merely a change produced by a variable population of companies."

Table 4-1 from Walkinshaw (1985) shows the number of companies providing samples as well as the total number of samples analyzed per year from both core and non-core companies.

The results of these tests and their interpretation in terms of risk reduction are presented in Section 4.3.1.

Table 4-1: Summary of Company Types Providing Blood Samples

YEAR	NUMBER OF COMPANIES	NUMBER OF CORE ¹ COMPANIES	NUMBER OF NON- CORE ² COMPANIES	TOTAL NO. OF BLOOD SAMPLES/YR.
1979	61	31	30	9,279
1980	69	31	38	10,144
1981	86	31	55	9,312
1982	148	31	117	12,868
1983	156	31	125	12,372
1984	171	31	140	13,602

- Notes: 1. Core companies are those that had submitted at least one sample for each year 1980 to 1984.
2. Non-core companies had submitted at least one sample for any of the five years, 1980 to 1984.

4.2.3 Collection of Expenditure Data

(a) Industry Expenditures

A review of Scotts Industrial Directory (15th Edition, 1984) indicated that there are approximately 126 firms in Ontario which are engaged in industrial activities which involve the production or utilization of lead or lead compounds. This estimate is reasonably consistent with the 171 firms from which blood lead samples were obtained by the Ministry of Labour (identities of these firms were held confidential). Table 4-2 provides a breakdown of the number of firms identified in this study by type of activity and employment size. Based on rough assumptions of average employment it is apparent that the 55 firms employing more than 50 employees account for approximately 85% of employment. For this reason, and because of budget constraints attached to this study, it was decided to focus information collection activities on these 55 firms. Forty-four firms in this group are located in the southern industrial heartland of Ontario. Letters inviting participation in the study were sent to these 44 firms. Of these firms, 10 participated in the interview program and provided expenditure information in varying degrees of detail. Table 4-3 shows a breakdown of firms contacted by mail and firms participating according to the type of industry. Personal interviews were conducted with senior plant managers. Confidentiality of participation was assured. Questions were asked regarding the production activities and size of the firm, lead exposure reduction measures implemented, the costs of these measures, and the bases and rationales underlying the firm's decision to invest in worker health and safety improvements.

The actual sizes of firms interviewed varied from 33 to 454 plant employees, and are summarized as follows:

- less than 50 employees	1 firm
- 51 to 100 employees	1 firm
- 101 to 200 employees	4 firms
- 201 to 400 employees	3 firms
- more than 400 employees	1 firm

Table 4-2: Number of Lead Producing or Using Firms in Ontario by Type and Size

TYPE OF FIRM	NUMBER OF EMPLOYEES			
	1-20	21-50	51-100	+100
Mining, milling and concentrating	0	0	1	0
Primary smelting and refining	0	0	0	1
Secondary smelting and refining	2	0	2	2
Brass and bronze foundries	13	6	3	1
Metal fabrication	15	6	4	6
- alloys				
- castings				
- rollforming				
- solders				
- welding				
Storage battery	5	0	4	10
Lead Compounds	4	4	1	2
- including TEL manufacture				
Oxides & Pigments	8	2	3	4
Rubber & Plastic	0	1	1	6
Leaded glass	5	0	3	0
Total No. of Firms	52	19	22	33
Assumed Avg. Employment per Firm	10	35	75	200
Estimated Total Employment by Employment Category	520	665	1,650	6,600

* Obtained from Scotts Industrial Directory (15th Ed.). Firms are categorized by plant employees where possible. Otherwise, total employees.

Table 4-3: Categories of Contacted and Participant Firms

TYPE OF INDUSTRY	NUMBER OF FIRMS 50+ EMPLOYEES	NUMBER OF FIRMS CONTACTED	NUMBER OF PARTICIPANT FIRMS
Mining, milling and concentrating	1	1	0
Primary smelting and refining	1	1	0
Secondary smelting and refining	4	4	1
Brass and bronze foundries	4	3	0
Metal fabrication	10	9	1
Storage battery manufacture	14	9	3
Organic lead compounds manufacture	3	3	1
Oxides and pigments manufacture and use	7	5	3
Rubber and plastic processing	7	6	1
Glass product manufacture	3	3	0
Total	54	44	10

Nine of the participating firms provided some degree of cost data.¹ The information varied from a detailed breakdown of expenditures over a number of years to a ballpark estimate of total expenditures in 1985 extrapolated back over several years with appropriate corrections for inflation. In general, cost information was difficult to obtain, not because of unwillingness to disclose such information, but due to its unavailability in the format requested. Few firms have accurate records differentiating expenditures made specifically for lead exposure reduction versus expenditures for other health and safety related purposes. In many cases there was no specific budget for such expenditures, and measures had multiple underlying purposes in addition to lead exposure reduction. Expenditures were classified into pre and post-regulation time periods to determine if there was any incremental effect attributable to the regulation.

The use of lead amongst the participant firms varied in degree from simple soldering, to recyclable use as a rubber curing agent, to basic raw materials and products. Table 4-4 presents a breakdown of participating firms by industry and process. Participants' estimates of revenue from lead-related products vary from as low as "less than 5%" to 100% of total plant revenue. The average of those figures is 75% of total plant revenue.

(b) Government Expenditures

Government expenditures on reduction of occupational exposure to lead in Ontario are focused in the enforcement activities of the Designated Substances Enforcement Unit of the Ontario Ministry of Labour. Information on historical enforcement activity levels and costs were provided by representatives of the Unit (J. Wilson, pers. comm.). An attempt was made to distinguish between pre-regulation and post-regulation expenditure levels to determine the incremental activities and costs associated with the regulation.

¹ A trend observed in the interview process indicated that firms of substantial size generally had lead control programs in place prior to the introduction of the 1981 regulation respecting lead. Although many firms required some adjustment to their programs, major expenditures in most cases took place prior to the 10-year period which was investigated. For this reason, cost information may not be representative. The hazards associated with lead in the workplace have been recognized by industry, and regulated by government, albeit in a more ambiguous manner than at present, for many years. The larger firms appeared to have had adequate controls in place, and procedural changes were all that was required under new legislation in 1979 and 1981. It may be the case that smaller firms were affected to a greater degree by the new legislation, and the expenditures per employee in these firms is likely to be radically different from that observed in this study.

Table 4-4: Categories of Firms by Industry and Process

PROCESS	FIRM									
	LEAD PIGMENT USERS OR MANUFACTURERS			STORAGE BATTERY MANUFACTURERS			OTHERS*			
	A	B	C	D	E	F	G	H	I	J
Mixing or Handling of Powdered Lead	X	X	X	X	X	X	X			
Spraying of Lead Liquids		X	X							
Low Temperature Handling of Lead Liquids		X	X						X	
Smelting or Handling of Molten Lead				X	X	X	X	X	X	
Alloying							X		X	
Grinding, Cutting, Sanding of Lead-Containing Products							X	X	X	
Soldering										X

* Includes rubber product manufacturing, secondary smelting, metal fabricating, and TEL manufacture.

4.3 Results

4.3.1 Evidence of Risk Reduction from Ontario Blood Sample Data

Table 4-5 presents the results of blood level concentration analyses as conducted for core companies (from Walkinshaw 1985). The results for core companies were selected for determination of risk reduction to avoid any bias which might be introduced by a changing composition of reporting companies.

The survey results indicate quite clearly that blood lead levels in Ontario's occupationally exposed population have dropped dramatically over the last six years, particularly since 1981.

The proportion of results in the lowest category, less than or equal to 0.29 mg Pb/L, has doubled from 27 percent to 54 percent. In the higher levels, 0.50 to 0.69 mg Pb/L and 0.70 mg Pb/L, the proportion has dropped to 37 percent and 11 percent of 1979 values respectively. The decrease in blood lead levels of all the companies, and of just the core companies, are similar to each other and, to a lesser extent, to those of the non-core companies. The non-core group is more variable in composition and thus more likely to provide more variable results.

From these data we derive a reduced average risk of having a blood lead concentration in excess of 0.70 mg Pb/L as follows. We have chosen the 1981 to 1984 period as the time frame for measuring reduction to coincide with the coming into force of the provincial lead regulations and with the structuring of our collection of expenditure data.

(i) The risk of blood lead concentration equalling or exceeding 0.70 mg Pb/L in 1981 is 4.0%. This is interpreted as a probability that 40 workers out of 1,000 tested will have a concentration in excess of 0.70 mg Pb/L.

(ii) The risk of blood lead concentration equalling or exceeding 0.70 mg Pb/L in 1984 is 0.9%. This is interpreted as a probability that nine workers out of 1,000 tested will have a concentration in excess of 0.70 mg Pb/L.

(iii) Risk reduction is therefore calculated to be:

40 events per annum per 1,000 employees
- 9 events per annum per 1,000 employees
= 31 events per annum per 1,000 employees

4.3.2 Expenditures on Risk Reduction

(a) Industry Expenditures for Lead Exposure Reduction

The measures taken by the firms interviewed to reduce lead exposure are described in Appendix 4.3

Table 4-5: Breakdown of Blood Lead Results for Core¹ Companies

YEAR	RANGE mg Pb/L	0.29 mg Pb/L	0.30-0.39 mg Pb/L	0.40-0.49 mg Pb/L	0.50-0.69 mg Pb/L	0.70 mg Pb/L	TOTAL NO. OF SAMPLES/YEAR
1979		26.8%	14.3%	16.4%	35.7%	6.8%	8,261
1980		30.8%	14.2%	16.9%	32.6%	5.5%	8,925
1981		40.3%	16.0%	15.3%	24.4%	4.0%	8,298
1982		40.3%	16.4%	17.1%	23.8%	2.4%	9,096
1983		48.8%	17.1%	15.7%	16.7%	1.7%	8,558
1984		53.7%	17.3%	15.0%	13.1%	0.9%	9,906

Notes: 1. Core companies are those that had submitted at least one sample for each year 1980 to 1984.

Nine of the 10 firms interviewed provided some expenditure information for the period 1976-1985. The information detail is variable, ranging from a simple estimate of 1985 expenditures, extrapolated back with assumed corrections for inflation, to a year-to-year breakdown of expenditures. Annual costs were in some cases broken down into capital, medical salaries, medical monitoring, incentives, protective equipment, protective clothing, and training. In other cases, some or all of the above costs were stated as a lump sum.

The cited expenditures have been summarized on the basis of a number of assumptions. In order to aggregate the collected data in a useable form, the following assumptions were made:

- The number of employees at each plant remained constant through the survey period. Given the difficulty of firms to provide a time series of employment data and the diversity of product types it was assumed that employment level bias would balance out amongst firms.
- Expenditures stated only for 1985 as recurring costs are assumed to be equivalent for the years 1976 through 1985, based on 1985 dollars. Discussions with plant operators were used to confirm this assumption.
- Expenditures stated for a particular year as one-time costs, are corrected to 1985 dollars based on an assumed 4% per annum inflation rate, and the following correction factors:

<u>Year</u>	<u>Correction Factor</u>
1976	1.4233
1977	1.3686
1978	1.3159
1979	1.2653
1980	1.2167
1981	1.1699
1982	1.1249
1983	1.0816
1984	1.0400
1985	1.0000

Total expenditures were then calculated for each firm over the 10-year period, and broken down into pre-regulation (1976-1980) and post-regulation (1981-1985) years. Based on these figures, the number of years for which information was available, and the number of employees at each firm, an estimate of the annual cost per employee was calculated for each firm according to the following formula:

$$\text{Annual Cost per Employee} = \frac{\text{Total Corrected Expenditures from Available Data}}{(\text{Number of Employees}) (\text{Number of years for which Information is Available})}$$

Table 4-6 displays these figures.

On first glance, it appears that the introduction of new regulations in 1981 did not cause great increases in lead exposure risk reduction expenditures for the industry sector surveyed.

Overall, the expenditure per year, per employee, increased only 2.6%. However, when one considers that firm G decreased their expenditures by 63.9% over the same period, and influenced the average in this way, the remaining eight firms, on average, increased their annual expenditure per employee by 37.6%. This increase is more in keeping with the expected rise in expenditures in the post-regulation period. Of the nine firms supplying expenditure information, five had increased expenditures in the period following the new regulations, and only two firms experienced decreases. Firm E sustained a large increase partially due to the commissioning of a new plant in 1981, and the large capital expenditures associated with it.

In general, expenditures may be categorized into two groups: those made on a recurring, or ongoing basis, such as protective clothing and equipment purchases, training, medical and air monitoring, medical and lab staff salaries, incentives, and maintenance, and those made on a one-time basis, such as new equipment purchases and installation, and upgrading of existing equipment. Ongoing expenditures tended to remain relatively constant over the years, the fluctuations in total expenditure therefore resulting from increases or decreases in capital spending from year to year. This was best displayed by Firm E, which constructed a new plant in 1981, and Firm G, which poured capital into its plant in order to improve conditions to both the interior and exterior environments of their plant in the early 1970s.

Firms earning 90-100% of their plant revenue from lead-related products tended to spend more on risk reduction. Firms C and H had an annual cost per employee of average or below average levels, and earn less than half of their plant revenue from such products.

(b) Government Expenditures for Lead Exposure Reduction

Government expenditures for enforcement of the lead regulations in Ontario were provided by the Designated Substances Enforcement Unit of the Ontario Ministry of Labour (J. Wilson pers. comm.). Activities of the Enforcement Unit are more fully described in Appendix 4.3(b) of this report.

The cost of enforcement activities is in the \$375,000 per year range, and has been relatively constant since 1981, when designated substance regulations related to lead were imposed. A breakdown of these costs is presented in Table 4.7. The above figure does not include prosecutions undertaken by the Legal Services Branch of M.O.L. Laboratory analysis costs include only air samples and bulk samples (e.g. waste paint, other lead substances). Analyses of blood and urine samples are not included.

Although no cost data were available for the period 1976 to 1980, the Ministry of Labour has stated that inspection-related expenditures increased

TABLE 4-6

EXPENDITURE INFORMATION

FIRM	INDUSTRY	NUMBER OF EMPLOYEES	PERCENTAGE OF REVENUE DERIVED FROM LEAD-RELATED PRODUCTS	TOTAL CORRECTED EXPENDITURES FOR LEAD EXPOSURE REDUCTION 1976-1985 (Number of Years Data is Available)	BREAKDOWN OF CORRECTED EXPENDITURES BY PERIOD (Number of Years Data is Available)		AVERAGE ANNUAL EXPENDITURE PER EMPLOYEE		PERCENT INCREASE
					1976-1980	1981-1985	1976-1980	1981-1985	
A	Lead Pigment Manufacture or Utilization	33	90%	\$325,771 (10)	\$91,155 (5)	\$234,616 (5)	\$552	\$1,422	+157.6%
B		170	25%						
C		130	<5%						
D	Electric Storage Batteries	220	100%	\$1,229,112 (10)	\$515,557 (5)	\$713,555 (5)	\$793	\$1,098	+38.5%
E		110(1976-1980) 228(1981-1985)	100%	\$2,035,000 (10)	\$955,000 (5)	\$1,080,000 (5)	\$868	\$982	+13.1%
F		210	100%	\$1,787,628 (9)	\$253,765 (4)	\$1,533,863 (5)	\$577	\$1,345	+133.1%
G	Other*	132	100%	\$342,759 (10)	\$268,104 (5)	\$74,655 (5)	\$255	\$71	-72.2%
H		247	40%	\$2,295,834 (7)	\$2,006,203 (5)	\$289,631 (2)	\$3,040	\$1,097	-63.9%
I		90	90%	\$1,350,000 (10)	\$500,000 (5)	\$850,000 (5)	\$405	\$688	+69.9%
J		454	100%	\$1,480,000 (10)	\$740,000 (5)	\$740,000 (5)	\$1,644	\$1,644	0%
TOTAL				\$3,061,600 (10)	\$1,525,000 (5)	\$1,536,600 (5)	\$672	\$677	+0.7%
AVERAGE		186		\$13,907,704	\$6,854,784	\$7,052,920	\$978	\$1,003	+2.6%

*These include rubber product manufacturing, secondary smelting, metal fabricating, and TEL manufacture.

Table 4-7: Annual Costs of Enforcements of Designated Substance Regulations
with Respect to Lead (Approximate 1985 \$)

1. Occupational Health Branch (Ontario Ministry of Labour)

i) Inspection Services

a) Medical Consultants	\$ 34,500
b) Nursing Consultants	107,400
c) Industrial Hygienists	31,000
d) Engineering Consultants	2,700
e) Combined Inspections	<u>4,000</u>

\$179,600

ii) Monitoring and Air Sampling 94,000

iii) Laboratory Analysis 32,000

2. Industrial Health and Safety Branch (Ontario Ministry of Labour)

i) Inspection Services 69,000

TOTAL \$374,600

dramatically following the implementation of the new regulations. These increases were brought about by a variety of factors.

A concerted effort was made to identify all firms using lead, thus the total number of firms subject to inspections increased. These results were obtained partially due to Ministry detective work and partially due to voluntary industry information. The frequency of the inspection cycle was also increased for most firms. In addition, the scope of each inspection expanded. The cumulative effect of these changes was a large increase in government expenditures in the cyclical inspection category.

The introduction of new legislation in 1981 resulted in increased awareness of the lead exposure problem among workers. This in turn led to an increase in the number of complaints and work refusals, each of which is responded to in the form of a workplace inspection. Critical injuries and fatalities related to lead in the workplace are rare, and an increase in inspections triggered by these was not observed. Overall, the greatest increase in expenditures was seen in the category of cyclical inspections.

4.3.4 Expenditures per Unit Risk Reduction

Expenditures per unit risk reduction are expressed on an average per employee basis estimated over the 1981 to 1984 period (four years).

- (i) industry expenditures per employee (1985 \$) aggregate 1981-1984:
\$1,003 (from Table 4-6) x 4 years = \$4,012.
- (ii) government expenditures per employee (1985 \$) aggregate 1981-1984:
\$374,600 (from Table 4-7) x 4 years divided by 9,435 employees
(from Table 4-2) = \$159.
- (iii) total expenditures (1981 to 1984) per 1,000 employees per unit risk reduction:
$$\frac{\$4,171 \text{ per } 1,000 \text{ employees}}{31 \text{ events per annum per } 1,000 \text{ employees (Section 4.3.1).}}$$

= \$135,000 per reduction of 1 excess blood lead concentration event per annum.

4.4 Discussion

4.4.1 Reliability of Estimates

The results of this study must be interpreted in light of the following points.

- (1) The number of firms which provided information (10) is very small relative to the total number of firms which are active in the production or utilization of lead in Ontario (likely between 125 and 175 firms). Given this limited sample we do not believe that it is possible to

extrapolate the expenditure derived in this study to the employee population in the industry as a whole.

(ii) The participating firms were typically involved in manufacturing processes that used some form of refined lead as their input. Firms engaged in the primary production and primary refining of lead are not included in the participating group. The unique nature and large size of these firms might be expected to result in somewhat different expenditures for risk reduction.

(iii) It was generally observed during the industry interview process that participating firms considered their record in risk reduction to be very positive and that actions had typically been taken well in advance of the lead regulation coming into force. It is not unexpected that those firms with a positive record would be those firms which would agree to talk about their record. In terms of influence on the results of this study the expenditures may be biased upwards by this phenomenon as compared to expected results from the total population of firms.

(iv) The study was restricted to firms with 51 or more employees. There is a likelihood that smaller firms would have had to respond to a greater degree to the lead regulation (i.e. in terms of a control program) than larger firms. The potential bias of excluding these smaller firms is unknown.

(v) It should also be recognized that the risk reduction measured amongst the 31 "core" companies of the blood testing program has been related to the expenditures of the 10 participating firms.

Given confidentiality of the blood testing data, it is not possible to judge the correspondence (i.e. in size or process type) of these two groups.

4.4.2 Roles, Responsibilities and Rationales for Risk Reduction

(a) Industry

In attempting to determine the rationales and bases by which decisions regarding lead exposure risk reduction were made by industry, a number of factors were considered. These included the number of employees exposed but not directly involved in lead related tasks, the types and extent of potential exposure, the percentage of plant or company revenue derived from lead-related products, the organizational structure of the plant and firm, the medical and air-quality surveillance programs, the problem identification methods used, the solution identification methods used, who takes responsibility for decisions of various scales, how priorities are established, and the influence of government, industry associations, labour groups, media, community groups, and the public at large. On many of these points, responses were very similar, on others, they varied.

As was previously discussed, the processes involved in the manufacturing of lead related products are numerous and are used in varying combinations in different types of industry. Therefore the number of employees exposed to lead varies also. Exposure extent is generally listed in two ways. A worker may be exposed to high levels of lead for a short period of time on an infrequent basis. Other workers may be exposed to lower levels, but for extended periods of time, on a day-to-day basis. Generally, the former are outnumbered by the latter in an industrial setting, and most often they are members of both groups.

In industries where lead-related processes do not form a major segment of the total manufacturing activity, they may be segregated from the remainder of the plant such that the number of employees exposed is kept to a minimum. In other industries this is not possible, as lead-related processes are widespread. Of the 10 participant firms, the percentage of employees potentially exposed averaged 68%, with a range of from 6% to 100%. Two firms used shift rotation in the higher exposure areas to reduce total exposure to a particular worker. Overall, the majority of plant employees in participant firms were potentially exposed. Only one firm hired non-permanent staff, and primarily for vacation relief and peak production periods.

Responsibility for employee health and safety is for the most part segregated from other plant responsibilities, and is held by an individual of management status. Three firms claimed no individual held such a position, and so responsibility was held by the plant manager.

As required by law, each plant has formed a joint health and safety committee, consisting of four to 10 members, at least half of which are workers. These committees meet, on average, once per month to discuss health and safety issues. Half of the participant firms held additional meetings on a regular basis with other groups to discuss health and safety. These groups may consist of all workers from a particular shift or work area, or managerial level employees.

While each plant has its own joint health and safety committee, the six firms which have more than one plant communicate between the various groups, and may share personnel between plants. Three of the six have corporate groups with regional responsibilities. The remaining three allow the plants to run themselves with regard to this issue. Nine firms claimed to have representation in health and safety groups of various industry associations and industrial and occupational health associations.

Problem identification takes place in several ways. Visible problems are identified by the workers or shift supervisors through everyday activities, or by the safety supervisor through regular inspections. Maintenance checks determine whether a problem with equipment exists. Invisible problems are identified through some combination of air quality monitoring, blood-lead monitoring, and lead in urine monitoring. Monitoring programs vary from annual air monitoring and blood-lead monitoring to daily air monitoring, and (depending on previous results) quarterly to biweekly blood-lead monitoring.

The most common frequency of monitoring is approximately monthly for air, with both ambient air samples and personal air samples collected, and quarterly to monthly for blood-lead monitoring. Lead in urine is used by three firms on a more frequent basis than blood-lead testing, and in one case replaces blood-lead monitoring following three consecutive acceptable tests.

When a problem is identified, it is brought to the attention of the joint health and safety committee for discussions. In no case does the committee have authority to make expenditure decisions, but it has a role in making recommendations. Because the committee has representation from both workers and management, it is generally thought that the recommendations made by it are reasonable.

The groups responsible for identifying solutions are similar for all firms and depend upon the source of the problem. Each firm has a control plan and operating procedures which specify precisely how each job was to be performed. Therefore if a problem is identified in procedure, the hygienist, health and safety representative, nurse, shift foremen, or joint health and safety committee, would identify and implement solutions. Similarly, a problem with existing equipment may be solved by the maintenance people. If the problem is judged to be due to inadequate control systems, the firm's engineering and design groups, or consultant engineers, design a solution. Firms in the battery industry generally rely more heavily on outside consulting help than other firms.

It is the engineered solutions which are the cause of large risk reduction expenditures. Procedural and maintenance solutions are not very costly. All solutions are evaluated on the basis of feasibility versus efficiency versus cost, with the time frame weighing heavily as well. It is rare that such an engineering solution is discovered to be necessary as a result of the aforementioned problem identification routes. These measures are designed into the processing system, such that the problem is actually solved before it exists. None of the 10 firms has experienced a situation whereby they discovered through monitoring that their controls were inadequate.

Establishment of expenditure priorities is again very uniform among the 10 participant firms. Five firms listed health and safety as equal in importance to production, quality, return on investment, and the requirement to maintain sales. Four others stated that priority was not an issue. They felt that if the expenditure was required, then it would be made, no matter what other expenditures were also on the table for discussion.

Only six firms have a specific health and safety budget, which in all six cases was established on the basis of past expenditures, experience, and new programs. Even these firms, though, did not restrict risk reduction expenditures to these budgets. Some expenditures which could be classified as risk reduction expenditures were absorbed into the operating budget, indoctrination budget, payroll budget, and maintenance budget. Four of six firms with health and safety budgets have segmented their budget into such categories as training, hospital supplies, protective clothing, respiratory

protection, medical salaries, outside contractors, and capital. The remaining two simply have a lump sum budget, which was drawn upon when necessary. None of these budgets could sustain major capital expenditures. These would have been absorbed into an overall plant budget.

The four firms without health and safety budgets operate on the basis that ongoing expenditures would be drawn from other budgets, as above; if a large capital expenditure was required, it would be drawn from the overall plant budget wherever there was room. As previously discussed, health and safety expenditures were rarely, if ever, turned down.

As in any business, the persons responsible for making expenditure decisions assess the size of the expenditure. There are no industry trends with regard to these matters, it is strictly a matter of corporate structure. In three cases, the director of personnel had responsibility for small expenditures. In all cases, either the plant manager or a management committee had responsibility for expenditures of up to approximately \$1,000.00, in most cases with input and advice from health and safety groups and other managers. Where a major expenditure was involved, and a head office existed, the responsibility fell to a regional manager or general manager. If there was no head office, the most senior management at the plant level had final authorization responsibility.

Relative cost-effectiveness is difficult to determine with all control programs, but it is generally felt that productivity and quality are increased, and staff turnover, absenteeism, spills, and seriousness and frequency of accidents are decreased, when a healthy working environment is provided.

External influences to the decision-making process are few. But in some cases, pressure can be great. As previously discussed, one participant firm responded to media attention by pouring capital into health, safety, and environmental programs in the early 1970s. Most firms felt that media pressure has potential for causing action, but that it has not occurred in the lead industry in general.

Labour groups only appear to have influence through the joint health and safety committee, and in some cases labour will support the firm against unreasonable worker demands. There has been very little labour activity with respect to this issue.

(b) Government

Responsibility for regulation of non-radiological occupational health and safety resides with the provinces. In Ontario the Occupational Health and Safety Division of the Ministry of Labour has this responsibility. The origins of the Division and its legislated mandate are described in Appendix 4.1.

Various Branches of the Division have responsibility for such functions as:

- o administering the Occupational Health and Safety Act and regulations
- o development of standards and guidelines to control exposure to toxic substances
- o provision of advisory, education and training services
- o provision of inspection and investigator services pursuant to enforcement of the Act
- o conduct of special research studies
- o provision of laboratory testing services

The Division works closely with industry and labour on all aspects of its functions, but particularly with respect to the development and application of workplace regulations and standards. In this regard the Division is guided by events in other jurisdictions and by its own program of health and regulatory research.

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Note: Industrial participants' names have been retained as confidential at their request.

Appendix 4.1 Background to the Ontario Occupational Health and Safety Act and Regulations

Prior to 1978, Ontario government health and safety groups were disseminated amongst various government divisions. Occupational health was the responsibility of the Ontario Ministry of Health, while the Ontario Ministry of Natural Resources held responsibility for mine safety, and the Ontario Ministry of Labour dealt with industrial and construction safety. Regulation and control of toxic substances in Ontario, including lead, was effected by the Industrial Safety Act, 1971; the Construction Safety Act, 1973; and the Mining Act, R.S.O. 1970. Occupational exposure to lead was regulated primarily by Ontario Regulation 279/72, and previously Ontario Regulation 196/64, under the Industrial Safety Act.

In 1978, the Occupational Health and Safety Division of the Ministry of Labour was established, incorporating all of the above groups, and thus bringing the responsibility for health and safety in all types of industry under one roof. Work began immediately to produce an Occupational Health and Safety Act and additional specific regulations regarding matters of a more specific nature. Notice of intent to regulate specific substances (including lead) was published.

In the ongoing process of updating and improving the regulatory system, the amalgamation of health and safety groups from the Ontario Ministries of Health, Labour and Natural Resources was perceived to be timely. Through the amalgamation, government would reduce duplication of effort, and be better able to administer the applicable regulations. The obvious first task of the new division was to revise the existing acts and regulations and merge them into a single act, with appropriate regulations.

The new Occupational Health and Safety Act was based on previously existing acts: the Industrial Safety Act, the Construction Safety Act, and the Mining Act. A draft of the proposed Occupational Health and Safety Act was published in 1978, and public comment was invited. Following a period of public response and revisions to the proposed act, it became law on October 1, 1979.

Similarly, in August 1978, a draft regulation with respect to lead was published in The Ontario Gazette to encourage public involvement and participation in the development of regulations.

As required under the new Occupational Health and Safety Act, section 22, notice of intent to designate lead was published in June of 1980, and in August of 1980, the proposed regulation relating to the designation of lead was again published. Public comment was similar to that relating to the 1978 draft regulation. The proposed regulation then was revised, presented to interested parties and discussed at a March 1981 public meeting.

After an additional comment period, the revised regulation, background material and a Ministry analysis of comments received following the public

meeting were sent in April 1981 to the Advisory Council on Occupational Health and Occupational Safety for review. The Advisory Council's responsibility was to analyze the process by which standards were set, and regulations produced, and to provide advice on these matters. The final, revised version of the lead regulation was submitted to the Advisory Council on June 3, 1981, prior to final Council comment.

On July 22, 1981, the regulation respecting lead was made by His Honour the Lieutenant Governor in Council, and filed with the Registrar of Regulations on August 14, 1981, on which date it became law.

Appendix 4.2 Available Measures to Control Occupational Exposure to Lead

As there is a variety of processes producing lead exposure hazards, so there is a variety of measures which can be taken to control exposure, and protect the worker. They range from simple worker hygiene practices, to hooded ventilation and complete enclosure. Not all measures are practical in every situation, however.

As has been discussed, the greatest hazard results from the various forms of airborne lead. Separating a source from the general working environment significantly reduces lead levels outside of the immediate area. This method is termed "isolation" and is only effective when workers remain outside the barrier. A similar, but more effective, control is termed "enclosure". Where no direct contact by a worker is required, and a particular process is achieved entirely through mechanical means, the system can be completely enclosed, and tightly sealed. This method is effective, but periodic maintenance will create periodic higher levels of exposure.

Ventilation may be used to improve conditions in many situations. It does not necessarily separate the source from the worker, but if planned properly is an effective method of removing the offending contaminated air, and supplying clean air. By combining ventilation from a source with a forced clean air feed, an air flow can be created in a work area to actually flood workers "upwind" of a source with clean air.

A very effective, but often impractical, measure is product substitution. Replacement of lead and lead compounds with some other material is possible in some processes. For example, lead pigments may be replaced by non-lead pigments, and TEL and TML may be replaced by non-lead anti-knock compounds in gasoline. In other processes however, lead is the best, or the only, substance suitable for its purpose, and so product substitution becomes impractical. In many cases, the substitution of another product or material for lead must take place gradually. Such is the case with the phasing out of the use of lead in automobile fuels.

Process changes are another method that can be effective, but are not always practical. Some examples are replacement of mechanical with manual sanding or filing, and replacement of spray painting operations with brush painting. Each of these measures would likely achieve both a lower airborne lead level and, unfortunately, a lower efficiency. Replacement of dry methods with wet, such as in sanding, filing, or grinding, or in the handling of a lead-containing slurry or paste rather than a powder, can be effective ways of reducing airborne lead without seriously affecting efficiency. Airborne fumes can be reduced by lowering process temperatures when working with molten lead to below 500°C. Process changes are often prompted for reasons of product enhancement or productivity gain; improved health and safety conditions are often viewed as a co-product or by-product of the change.

A well-designed and engineered control program must be supplemented by adherence to strict work and hygiene practices. Such procedural control

measures can be very effective, but should never pre-empt engineered control measures. Instead, to gain maximum effectiveness, (i.e. minimum exposure) procedural measures should be used in association with engineered controls.

Proper housekeeping procedures are important in reducing exposure. A well planned work area should have as few surfaces or spaces in which contamination may accumulate as possible. Hygiene facilities and practices can reduce both exposure to the worker, and removal of contaminants from the work site. Proper hygiene practices may include washing of hands before every break, and prior to eating, drinking, or smoking. A ban on food, drinks, and cigarettes in the work area reduces ingestion of contaminants. Protective clothing can reduce direct contact with contaminants and can range from simple gloves and coat, to fully encapsulated suits with respirators. Hygiene facilities refer to changing and washing areas, and can include everything from simple wash and shower rooms, to a locker-shower-locker system. The double locker system is effective in preventing removal of contaminants. Each worker has clean "street" clothes in one locker, and must pass through the shower facility to reach them. Work clothes are kept in the other lockers, and are laundered regularly.

Administrative controls are another method which can reduce the exposure to individual workers. These controls do not, however, reduce actual levels in the work area. By rotating job schedules, the time that a single worker is exposed is reduced. Work rest schedules may also reduce time of exposure.

All of the above-mentioned procedural controls are most effective when the worker has an awareness of the hazard, and of the reasons why the controls are necessary. Human error causes these controls to be less reliable than engineered controls, but awareness can reduce human error. For this reason, employee education and training, as well as good employer/employee communication, are vital to the effective use of any procedural controls.

Due to a variety of forms of lead, processes involving lead, and available control measures, often the best control is a combination of all the above-mentioned methods. Each situation, however, is different, and therefore requires its own set of controls, designed specifically for the site.

Appendix 4.3 Measures Taken to Reduce Risk

(a) Industry Activities

The control of lead exposure in the workplace is a complex problem involving complex solutions. The control programs effected by the 10 participant firms reflected this complexity in that each had a unique combination and design of control measures. Within firms which had two or more plants, each plant had a program designed specifically for its own situation. While certain measures were put to use to varying degrees by all participant firms, others were common only in a particular industry, or across several industries, but not all.

Common to all participant firms was ventilation. It was the only engineered control common to all firms, and was by far the most important measure used, as the most common and dangerous forms of lead exposure are airborne. The layout, design, and power of the ventilation systems varied, depending on the plant layout, number of work stations where there was a potential exposure hazard, and the degree of the potential hazard. In all cases, the vented air was filtered to prevent emission of lead to the external atmosphere.

Source-specific ventilation was generally used at locations where a high release of lead was expected. In these cases, vent hoods were placed as near as practically possible to the point of release. Air supply for these vents was the ambient plant air.

In some particularly high exposure operations, such as the skimming of dross from tanks of molten lead, or in the packaging of powdered product, a combined ventilation/air feed system was put to use. One firm required some manual handling in the packaging of its powdered product due to inaccuracies in its automated product measuring equipment. To protect the worker involved in this operation, an air flow was created (a "wind tunnel" effect) through the use of venting and air supply, in which the worker was stationed "upwind" of any potential release of lead. Another firm, involved in manual drossing of a tank of molten lead, had placed their vents and air supply such that the worker was flooded from above with fresh, clean air. These examples were essentially the same concept, with slightly different layouts due to differences in details of the work area.

The ventilation/air feed combination was used in locker areas of two firms to maintain a positive pressure in the "clean clothes" lockers. Locker and change rooms, where provided, were generally ventilated.

Other engineered measures included isolation and enclosure of particular processes and work areas prone to release of lead contaminants. While all firms interviewed used isolation/enclosure to some degree to reduce exposure, industries in electric storage battery manufacturing, leaded pigment use, and rubber manufacture, listed no expenditures for this type of measure over the survey period (1976-1985). Other industries employed this strategy primarily in trash and vacuum bag transport and dross tanks, in packaging and loading

areas, and in improved sealing of dross tanks, blending tanks, and cooling water systems. Enclosure was combined with ventilation in some cases to create a negative pressure within closed systems as a further guard against leakage.

Product substitution was employed by four firms; two each of leaded pigment users, and manufactured goods producers. In the case of substitution of non-leaded pigments for leaded pigments, the change was made specifically to eliminate lead from the product. However, in the other cases, substitutions were made to increase production efficiency and product quality, and lead exposure was reduced as a result. Replacement of a steel part with a plastic part resulted in reduced soldering requirements, and coating of a metallic lead product with a non-leaded substance allowed final grinding and sanding to be completed without creation of lead dust.

Engineered process changes effected by half the participant firms involved mainly increased automation, resulting in decreased manual handling of products, and therefore decreased exposure. Two firms made these changes in the interests of production efficiency, rather than lead exposure reduction. One purchaser of lead oxides installed equipment in storage facilities to prevent release of dust to the plant caused by overfill.

Procedural exposure reduction measures were used by all firms to supplement engineered measures, but to varying degrees. Respirators are, at the least, made available for worker use. In most cases, firms required their use at particular work stations. The type of respirator used was dependent upon the conditions of the work area, and they varied from half-face/cartridge, through full-face/filtered positive pressure, to full-face/air supplied positive pressure. Generally they were used in isolated areas such as loading or product packaging, drossing operations, and spraying, and are used as a contingency, rather than a control. Their use in some maintenance operations was common to all participant firms.

Protective clothing was used by all firms, again to varying degrees. Protection ranges from complete head-to-toe protection, with boots, pants, shirts, coats, gloves and coveralls provided, or tyrek (non-dust-retentive fabric), coveralls, boot covers and head covers provided, to simply gloves, boots and aprons provided, with the worker supplying his own work clothes. Laundry service was provided for company-supplied clothing, and in some cases for worker-supplied clothing. Eight firms provided a double locker system whereby the worker changed into clean clothing prior to leaving the plant, and left soiled clothing behind to be laundered.

Personal hygiene practices were stressed as a method whereby the worker can protect himself. Shower and washing facilities were provided by all firms, but showering was not mandatory in all firms. Generally, where the double locker systems were provided, showering was mandatory in order to keep the "clean" locker area clean. Most firms have banned smoking, drinking and eating from the work area, and workers are reminded to keep their hands and arms away from their eyes, nose and mouth while working.

All firms employed a policy whereby each worker is at least partially responsible for maintaining a clean work station. In addition, however, general plant housekeeping was necessary and was accomplished through the use of central vacuum systems, portable vacuum systems, wet sweeping, wet mapping, and wet scrubbers.

The key to successful procedural control measures is employee awareness. Participant firms have different methods of achieving this goal, and training programs vary from new employee induction presentations, with or without annual repetition, to monthly health and safety meetings. Reminders are posted frequently on the plant bulletin board to keep workers aware. It was generally felt that today's workers are becoming increasingly aware of and increasingly concerned about possible health effects resulting from the work environment.

Administrative controls such as rotating shifts, to expose individual workers on only a periodic basis, were used at several firms, and one lead-based pigment user has introduced product safety coding, to show the employee what substance he is dealing with and how to properly handle it.

(b) Government Activities

Current activity on lead risk reduction by government is restricted to the Occupational Health and Safety Division of the Ontario Ministry of Labour. Enforcement of the lead regulation is the only activity on which significant spending currently takes place, however in the period 1976 to 1981 expenditures could be categorized into two groups: those relating to enforcement of then-existing regulations, and those relating to the development of the new Occupational Health and Safety Act, and the new Regulation Respecting Lead, made under the Designated Substances Program. Unfortunately, estimates of the cost to government of producing those new regulations are not available.

Current enforcement methods are based on plant inspections by Ministry of Labour personnel. These inspections are carried out by the Ministry's Designated Substances Enforcement Unit, with support from other groups within the Occupational Health and Safety Division. Inspections of a particular plant may be triggered by a variety of factors. The majority of plant inspections are cyclical inspections required for all firms listed as designated substance users or producers. Frequency of inspections varies according to a formula based on size of firm, amount of designated substance handled, type of designated substance, and several other factors. Occasional additional inspections may be conducted as a result of complaints, work refusals, critical injuries, or fatalities.

Additional occasional expenditures associated with the inspections are air and blood sampling and analysis and, in the event that an infraction is noted, Ministry experts and consultants are provided to the Enforcement Unit to assist the inspector in issuing a control order.

Most of the inspection work performed by Occupational Health Branch is provided at the request of the Industrial Health and Safety Branch. The role of Medical Consultants is to advise on the medical implications of plant conditions. Nursing Consultants audit the industries' medical surveillance programs. The Industrial Hygienists' role is to perform site visits to audit exposure to workers and recommend appropriate remedial measures if necessary. The Engineering Consultants provide advice on exposure control implementation and construction.

Firms undergoing inspections must provide upon request their records of air monitoring, blood-lead monitoring (on an anonymous basis), details of their control program, and any other relevant material which may be required. None of this information is regularly collected by the Minister of Labour other than during inspections. The employer is responsible for notifying the Chief Physician, Occupational Health Medical Service of the Ministry, whenever a worker is deemed fit with limitations, or unfit for work due to a condition resulting from exposure to lead.

CASE STUDY NUMBER 5

PURCHASE AND USE OF CHILDREN'S AUTOMOTIVE SEAT RESTRAINTS

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5. PURCHASE AND USE OF CHILDREN'S AUTOMOTIVE SEAT RESTRAINTS

5.1 Introduction

5.1.1 Background and History

In the past 10 years or so in Canada there has been an increasing number of children using child restraints¹ while travelling in a motor vehicle. With government promotion and introduction of child seat legislation, more and more consumers and parents have become aware of the protection afforded to children by child restraints, and usage of these devices has increased accordingly.

In response to growing consumer concerns in the late sixties regarding the extent of protection provided by various brands and models of car seats sold in the market place, both the U.S. and the Canadian governments introduced regulations governing the standards of these devices. The Canadian standard was introduced by the Department of Consumer and Corporate Affairs (CCA) in April 1972 under the Hazardous Products Act.

It closely resembled the U.S. standard issued a year earlier. The standard was subsequently revised in 1974 based on more stringent requirements. The revised standard prompted many debates. In 1978, the Minister of Consumer and Corporate Affairs appointed a Task Force to review the existing regulations on child restraint systems and other related issues. Among the Task Force's recommendations adopted by the Minister was that Transport Canada assume sole responsibility for the development of standards on child restraint systems. This became effective as of April 1981.

Since assuming this responsibility, Transport Canada has carried out extensive tests in the area of infant and child restraint systems and set minimum performance requirements for these systems. Today Transport Canada's efforts continue in testing and improving performance standards on child restraint systems.

Transport Canada's other activities include undertaking public education and information distribution programs aimed at promoting the proper use of all infant and child restraint systems, and administering periodic use surveys since 1984. Transport Canada also assembles accident report data from provincial sources and carries out related research.

At the provincial level, nine provinces in Canada have introduced legislation making the use of child restraints compulsory. Prince Edward Island is the only province with no child restraint law. The first province to introduce such a law was Saskatchewan in 1980. Other provinces followed in subsequent years. In Alberta, children born after December 31, 1984 are subject to the child restraint law. In co-operation with the federal government, these nine

¹ Child restraints in this report include infant, toddler and convertible safety seats and booster seats.

provinces have also been active in promoting the use of child restraints through public awareness campaigns.

The provinces are also the prime sources of data on usage rates and accident data.

5.1.2 Nature of the Hazard

In Canada, traffic accidents have been the leading cause of death among young children. Each year, approximately 5,500 children under the age of five years are injured or killed in Canada in traffic related accidents (Dalmotas, Dance, Gardner, Gutoskie and Smith 1984). The largest group of passenger victims of automobile accident induced death and injuries have been between one and five years of age (Verreault, Stulginskis, Keyl, Read and Pless 1982).

Traffic injuries and fatalities are a result of a number of causes, including the victim sustaining an impact or impacts, dislocation of the body or parts of the body due to sudden and severe body excursion and damages due to fire and/or explosion. But the majority of traffic injuries and fatalities are the result of the victim sustaining an impact or impacts in the event of a crash. According to U.S. Department of Transportation's National Crash Severity Study data, about 68 percent of moderate to severe injuries are produced in crashes of 30 mph (48 kmph) and below; this means that only a relatively small percentage of the moderate to severe injuries are produced by high speed crashes. Also, most fatalities occur in high-speed crashes, for example only 37 percent of fatalities occur to unrestrained occupants below 30 mph (48 kmph); the remainder are in very severe crashes above 30 mph (48 kmph) (U.S. National Transportation Safety Board 1985). These statistics suggest that the majority of injuries occur in non-severe crashes and which can be prevented by the use of restraint systems. Very severe crashes do occur and they can produce severe and fatal injuries to restrained or unrestrained occupants alike.

However, there are relatively fewer children involved in the high severity crashes than in the non-severe kind. High severity crashes are usually associated with high speed driving or drunken driving. Children are usually found in cars driven around town during the day, exposing them to crashes of a less severe nature.

Past research and laboratory tests, primarily related to adult occupant protection, and mostly carried out in the United States, point to three basic principles which are important to the development of a restraint system for the protection of an occupant in a crash. All three principles aim at reducing impacts to the occupant. These involve (1) distribution of the crash loads over the body into the region of the body that are best suited to withstand those loads, (2) limiting the severity of the loads on the body, and (3) limiting the motions of the occupant to prevent contact with interior structures and to provide what is known as "ride down" of the crash (i.e. the occupant is attached to the car, and as it stops, the occupant stops with it) (U.S. National Transportation Safety Board 1985). These principles have been

incorporated in child restraint design for some years both in the United States and in Canada.

5.1.3 Objectives and Scope

The main purpose of this case study is to determine the implicit willingness of individuals to pay for reduced risk of injury and mortality to young children through the purchase and use of child restraint devices.

Specifically, the study is to provide findings in the following areas:

- (a) a definition of risk and risk reduction;
- (b) statistical evidence of the relationship between risk reduction and use of child restraints; and
- (c) a measure or measures of the willingness-to-pay of individuals for risk reduction.

The research was carried out under the following parameters:

- (a) that the target group of the research is children in the age group of zero to five years;
- (b) that the research is focussed on the Canadian experience;
- (c) that with the exception of a small-scale survey, no primary research will be carried out; and
- (d) in examining devices designed for risk reduction, this study will only be concerned with child restraint systems commonly known as car seats (i.e. this study will not examine other methods of risk reduction, such as various designs of car structures which may contribute to occupant protection such as air bags).

5.2 Methodology

5.2.1 Definition of Risk

For the purpose of this study, risk is defined as the probability of a child between the age of zero to five years sustaining serious/major injuries or fatality in the event of an accident while riding in an automobile.

The decision to focus the definition of risk on serious and fatal injuries is based on the assumption that the main reason for parents to purchase and use a child restraint device is to reduce the probability of serious and fatal injuries, rather than minimal or minor injuries.

5.2.2 Documentation of Risk Reduction

Three main methods were used to document risk reduction. Statistical data bases were used to document actual risk reduction and a survey of parents was used to document perceived reduction. The methods employed are as follows:

The first method included reviewing pertinent literature on the cost-effectiveness of child restraints and on personal decision making

regarding purchase and use; consolidating the findings of key literature documents including surveys conducted in Calgary by the Injury Research Unit of the University of Calgary and others, and the cross-country surveys in 1984 and 1985 on the extent of proper use of child restraints, by Transport Canada.

The second method included assembling statistics on the comparative risk of serious injury and death for young children in automobile accidents between those who are restrained in a child restraint device and those who are not restrained. Ontario data were used, supplemented by Alberta data. Ontario data are the most detailed of all provincial traffic accident and injury data, and more importantly, they include statistics on non-injured occupants by type of restraint used. No other province in Canada collects this data. These statistics are essential to the calculation of the relative risk between the restrained and the non-restrained occupants. Also, Ontario has the longest historic statistical profile compared to other provinces. This was particularly useful for the purpose of determining trends and/or variations. Ontario data, similar to other provinces' originates from police reports on traffic accidents. They are available for the period 1977 to 1985, inclusive. Based on these data, two indices of risk reduction were developed:

- reduced absolute frequency of major/fatal injuries per 1,000 child (ages zero to five years) involvements in reported vehicle accidents due to the use of a child restraint as compared to no restraint. For the purpose of this study, this index will be referred to simply as the reduced frequency of sustaining serious/fatal injury.

- percentage reduction of the absolute frequency of major/fatal injuries per 1,000 child (ages zero to five years) involvements in reported vehicle accidents due to the use of a child restraint as compared to no restraint. This will be referred in the remainder of the report as percentage reduction of risk, and is derived from the following formula of calculation:

$$z = \frac{a/1000 - b/1000}{a/1000} \times 100$$

where z = percentage reduction of risk

- a = frequency of sustaining serious/fatal injury out of 1000 involvements where none of the children involved used a restraint of any kind

- b = frequency of sustaining serious/fatal injury out of 1000 involvements where all the children involved were restrained by a child restraint device

Alberta data are less detailed, and lack statistics on non-injured occupants. Only aggregated data for the period of 1978-1980, as reported in a previous study (Dalmotas, Dance, Gardner, Gutoskie and Smith 1984), are available. They were reviewed and compared with Ontario data.

With respect to the documentation of perceived risk reduction and analysis of decisions underlying the purchase and use of restraint devices, it was considered desirable to focus on decisions made in the absence of legislation requiring the use of such devices.

Given that child restraint legislation came into force in Ontario in 1982, it was considered unlikely that adequate responses could be obtained from parents for the period preceding 1982. Legislation in the province of Alberta came into force in 1983; it was therefore decided to conduct the survey in Alberta and to use the Ontario crash data as a empirical indicator of risk reduction.

A survey of 78 parents was conducted in the City of Calgary². A structured questionnaire was administered either by phone or in person to the volunteer respondent. A copy of the questionnaire used is attached in Appendix 5.1. Fifty-three respondents were daycare users (from 15 daycare centres in the city) and the remaining 26 were office workers including secretaries and professionals in selected Calgary offices. Only parents with children between zero and five years of age were interviewed. The primary purpose of the survey was to determine the following:

- child restraint use level
- expenditure data
- perceived risk and risk reduction
- willingness to pay for risk reduction
- factors affecting use and willingness-to-pay

The survey was conducted over a period of three weeks in August 1986. The questionnaire was pre-tested. Two trained interviewers conducted the interviews. All questions refer to the period before Alberta passed the Child Seat Law in November 1984. The purpose was to exclude the influence of legislation on the respondent's answers. The results were computer analyzed.

5.2.3 Collection of Expenditure Data

As described above, the survey was the only source of expenditure data. Respondents were asked for both the actual amount paid for their car seats and the year they purchased them. Using the annual consumer price index for Calgary, the dollar values were inflated to 1986 dollars.

The respondents were also asked two willingness-to-pay questions relating to their perceived relative risk reduction.

Attempts to derive expenditure data from literature research proved to be disappointing. Thus, the survey results were the only measure available.

² Seventy-nine respondents were originally scheduled to participate in the survey, however, one family could not be reached, leaving 78 completed interviews.

5.3 Results

5.3.1 Evidence of Risk Reduction from Ontario Accident Data

As suggested in the previous section, evidence of risk reduction was examined through three sources: literature review of past studies, especially pertinent government research; Ontario accident data; and a survey of Calgary parents. Evidence from the literature is discussed in Appendix 5.4.

Accident data pertaining to Ontario for the period 1977-1985 were obtained from the Transportation Regulation Development Branch of the Ontario Ministry of Transportation and Communications. The original source of the data was police reports. The Ministry only compiled the data and was not involved in the collection of data. Injury data were classified by none, minimal, minor, major and fatal. The differences between minimal, minor and major were that minimal referred to cases where no hospital visits were required, minor referred to cases where hospital visits were required but the victims were released upon treatment in the same day, and major refers to cases where hospitalization of the victims was required. These interpretations were generally standard across provinces.

The Ontario data were also classified by age, including the age groups of one, two, three, four, five, six, seven to 10, 11 to 15 and 16 and over. Furthermore, in addition to categorizing accident involvements by position in the vehicle, the Ontario data recorded the type of restraints used. The categories included the following: no restraint fitted, seat belt not used, seat belt used, child restraint used, unknown and other. For the purpose of this study, only the first four categories were used. According to officials of the Ministry, the last two categories were generally for unclear cases. Our study further collapsed the first two categories into one, because for the purpose of this study they are essentially identical. Also, our study was mainly concerned with risk reduction in major injury and fatal cases.

Tables 5-1 and 5-2 summarize the analysis of the Ontario data and calculate the risk reduction indices based on our definitions as discussed in Section 2.0. Appendix 5.2 provides the detailed data upon which the statistics in Tables 5-1 and 5-2 were derived.

Table 5-1 compares the frequency of major injuries per 1,000 child (zero to five years of age) involvements in reported vehicle accidents in Ontario between unrestrained cases and cases where child restraints were used for the period 1977 and 1985. For instance, in 1985, there was a total of 1,337 children between the ages of zero to five years, who were not using restraints of any kind, in vehicle accidents. Of this, 26 children sustained major injuries. Thus, the calculated frequency of major injuries per 1,000 child involvements, under the "unrestrained" category, as shown in Table 5-1 is 17.7. In the same year, a total of 1,181 children (ages zero to five) who were using child restraints, were involved in vehicle accidents. Of this, four sustained major injuries. Thus, the calculated frequency of major injuries per 1,000 child involvements, under the "child restraint used"

Table 5-1: Frequency of Major Injuries per 1,000 Child (0-5 Years of Age) Involvements in Reported Vehicle Accidents in Ontario by Type of Restraint Used, 1977-1985

YEAR	UNRESTRAINED (A)	CHILD RESTRAINT USED (B)	(C) = (A) - (B)	PERCENTAGE REDUCTION OF RISK OR CHILD RESTRAINT EFFECTIVENESS (%) (C)/(A)
1977	10.5	3.0	7.5	71.4
1978	15.7	2.7	13.0	82.8
1979	15.5	3.4	12.1	78.1
1980	16.0	0.0	16.0	100.0
1981	12.4	1.6	10.8	87.1
1982	19.1	2.3	16.8	88.0
1983	9.1	4.7	4.4	48.4
1984	23.0	3.0	20.0	87.0
1985	17.7	4.8	12.9	72.9
Mean	15.44	2.83	12.61	79.52
Std. Dev.	4.33	1.48	4.76	14.56

Source: Ontario Ministry of Transportation and Communications

Table 5-2: Frequency of Fatal Injuries per 1,000 Child (0-5 Years of Age) Involvements in Reported Vehicle Accidents in Ontario by Type of Restraint Used, 1977-1985

YEAR	UNRESTRAINED (A)	CHILD RESTRAINT USED (B)	(C) = (A) - (B)	PERCENTAGE REDUCTION OF RISK OR CHILD RESTRAINT EFFECTIVENESS (%) (C)/(A)
1977	1.4	0.5	0.9	64.3
1978	2.2	2.2	0.0	0.0
1979	2.1	1.0	1.1	52.4
1980	3.0	0.5	2.5	83.3
1981	3.6	0.4	3.2	88.9
1982	1.9	0.0	1.9	100.0
1983	0.8	0.0	0.8	100.0
1984	4.0	0.6	3.4	85.0
1985	6.4	0.4	6.0	93.8
Mean	2.82	0.62	2.20	74.19
Std. Dev.	1.68	0.66	1.83	32.03

Source: Ontario Ministry of Transportation and Communications

category in Table 5-1 is 4.8. Thus, the absolute risk reduction in terms of the frequency of major injuries per 1,000 child involvements is 12.9 (17.7 minus 4.8). This could have been interpreted to mean that out of 1,000 involvements, about 13 children could have been protected from major injuries if they had been restrained by a child restraint device, but about five children would still have sustained major injuries even if they were using a child restraint.

For the purposes of further analysis, actual risk reduction is estimated to be equal to the average difference in frequency of major injury over the 1977 to 1985 period: 12.6 events per 1,000 child involvements in reported vehicle accidents.

Another way to measure risk reduction is in percentage terms. Again, based on the above set of statistics, using child restraints reduced the risk of major injuries by about 73 percent (Table 5-1).

Over the 1977-1985 period, the average absolute risk reduction (in terms of reduced frequency of sustaining serious injury) was calculated to be 12.6/1000 (i.e. 15.4 minus 2.8/1000). This means that the effectiveness of child restraints, based on Ontario's 1977-1985 data, is about 80 percent in terms of protection of children from major injuries.

Table 5-2 presents calculations of risk reduction pertaining to fatal cases, using the same approach as Table 5-1. The average over the 1977-1985 period suggests that about two children out of 1,000 would have been protected from death caused by vehicle accidents if they had used a child restraint, but about one child in 1,000 would still have sustained fatal injuries even if they were using such a device. The effectiveness of child restraint in this case is 75 percent.

The above results compare favourably with Scherz's findings and the findings of other similar studies discussed in Appendix 5.4.

The Ontario Ministry of Transportation and Communications data also revealed an historic trend of increasing use of child restraint and an increasing trend of risk reduction (see Appendix 5.2). For example in 1977, there were a total of 18,266 reported child involvements in traffic accidents in Ontario in the age group of 0-5 years classified under the categories of no restraint used, child restraint used and seat belt used. Only about 10% of these children were wearing child restraints. Over 50% were using no restraints of any kind. The remainder (40%) used seat belts. By 1985, the total number of such involvements were reduced to 15,934. Among them, over 35% of the children used child restraints, and only 13% used no restraints of any kind. The remaining 52% used seat belts. This trend has clearly contributed to an overall reduction in the absolute number of injuries of all levels of severity. For example, there were 1820 children injured in 1977, regardless of whether they used child restraints or were totally unrestrained, versus 950 in 1984 and 1217 in 1985.

It follows from the above that in addition to reducing the risk of serious and fatal injuries, child restraints also had the effect of increasing the probability of children sustaining no injuries of any kind, and reduced the risk of minimal and minor injuries in the event of an accident. Over the 1977-1985 period in Ontario, among the non-restrained children involved in reported accidents, 79% on the average had no injuries, 12% had minimal injuries and 7% had minor injuries. Among those who were restrained in a child restraint, about 93 percent incurred no injuries, only 5% had minimal injuries and 2% had minor injuries. Table 5-3 summarizes these results. Available 1980 statistics from Alberta accident data show very similar patterns. Table 5-4 presents these statistics. A note of caution about the Alberta data is that the restraint used category does not distinguish between the specialized child restraints and the conventional seat belts. Despite this fact, the effects appear very similar.

5.3.2 Perceived Risk Reduction: Results of the Parent Survey

The survey of parents in Calgary who volunteered to participate resulted in only one non-response. Among the 78 respondents, 29 were male (37 percent) and 49 (63 percent) were female. There were 98 children under the age of six among the 78 households surveyed, giving the average number of children per household to be 1.3. Twelve percent of the children were under one year of age, 26 percent were 1 year old, 45 percent were between 2 and 3 years of age, and the remaining 17 percent were between 4 and 5 years.

All 78 respondents owned or otherwise operated a motor vehicle between 1980 and 1985. All 78 respondents had or have used an infant carrier or a child safety seat in this period. About 70 percent have used both, while only 3 percent have used an infant carrier only. The remainder (27 percent) have used a child safety seat only.

Seventy-three (96 percent) out of the 76 respondents who have ever used a child safety seat said that they always or almost always used the child safety seat when travelling with their children in their vehicles. Only three (4 percent) out of the 76 respondents said they used their child safety seats about half the time.

The majority (95 percent) of the respondents believed that car seats would result in large reduction in the risk of serious injury or death to children in the event of an accident, as compared to a child using no restraint.

In an attempt to quantify the perceived risk reduction resulting from the use of car seats, parents were asked to compare the percentages of children (under 40 lbs or 18 kg) who would receive serious injuries between those who were restrained in a car seat and those who were not restrained at all in a hypothetical car collision situation - a car travelling at 60 km per hour colliding head on into a stationary object. The average response was that 91 percent of the unrestrained children and 20 percent of the restrained children would have been seriously injured. Thus, the perceived risk reduction measured in percentage terms is 78 percent. This compares

Table 5-3: Percentage Distribution of Child Involvements in Traffic Accidents by Severity of Injuries by Restraint Usage in Ontario, Averaged over 1977-1985

INJURY SEVERITY	NO RESTRAINT	CHILD RESTRAINT
None	79.0	93.0
Minimal	12.0	5.0
Minor	7.0	2.0
Major	1.5	0.3
Fatal	0.3	0.1
Total	99.8*	100.4*

Source: Ontario Ministry of Transportation and Communications

* Due to rounding, the total does not always add up to 100 percent.

Table 5-4: Percentage Distribution of Child Involvements in Traffic Accidents by Severity of Injuries by Restraint Usage in Alberta, 1980

INJURY SEVERITY	NOT RESTRAINT	RESTRAINT
None	87.3	91.0
Minimal	6.5	5.3
Minor	5.0	3.2
Major	1.0	0.4
Fatal	0.3	0.1
Total	100.1	100.0

Source: Transportation Safety Branch, Alberta Transportation

remarkably favourably with the calculated risk reduction index (79.5 percent) derived from the Ontario data (see Table 5-1). Table 5-5 summarizes the analysis of the survey results on perceived risk reduction. Appendix 5.3 presents the analysis in detail.

The respondents were further asked to estimate the risk of children sustaining serious injuries if they were wearing seat belts instead of car seats, with all other conditions being equal. On the average, the respondents perceived that 48 percent of the children would have sustained serious injuries. This suggested a perceived percentage reduction of risk of 48 percent as compared to a child totally unrestrained.

Furthermore, based on the survey findings, the perceived effectiveness of car seats or child restraints over seat belts was that child restraints could reduce the risk of serious injuries by 57 percent when compared to seat belt. Table 5-5 summarizes these findings.

In conclusion, the perceived percentage reduction of risk or effectiveness of child restraints based on the survey of Calgary parents is very close to the actual estimates based on reportable accident and injury data in Ontario which averaged 80 percent over the 1977-1985 period. This represents a reduced frequency of sustaining serious injury of 13/1000.

5.3.3 Expenditures on Risk Reduction

Expenditures on risk reduction were derived from the survey. (Detailed statistics of selected analyses are presented in Appendix 5.3). Of the 76 respondents who had used a child safety seat between 1980 and 1985, 67 (88 percent) purchased their safety seats, and the remainder received their safety seats as a gift. None rented. Among those who purchased, 85 percent purchased them new, and 15 percent purchased them used.

After converting all purchased prices to 1986 dollars by applying the appropriate annual consumer price index of Calgary, the average expenditure parents spent per child safety seat was calculated at \$72, with the highest value at \$156 and the lowest value at \$21.

A scattergram analysis was carried out to determine if there is a relationship between actual expenditures on child restraint purchase and perceived risk reduction. The result is shown in Appendix 5.3. We found no apparent relationship.

Our survey also asked parents the maximum they were willing to pay for a child safety seat for the purpose of acquiring protection from injuries induced by automobile accidents to their children. Seventy-six out of 78 respondents answered the question. On the average, the respondents are willing to pay up to a maximum of \$746 for such protection or risk reduction. However, there is a wide range of maximum willingness to pay values, ranging from the lowest of \$60 to the highest of \$20,000, with the following distribution pattern:

Table 5-5: Perceived Risk and Risk Reduction Measured in Terms of Frequency of Serious Injuries per 100 Child (under 40 lbs or 18 kg) Involvements in A Hypothetical Head on Collision of An Automobile at a Speed of 60 kmph

	MEAN ¹	STANDARD DEVIATION
(A) Perceived Risk		
- Unrestrained Situation (A)	91.10	15.19
- Child Seat Used (B)	20.17	17.45
- Seat Belt Used (C)	47.77	22.04
(B) Perceived Risk Reduction		
- Child Seat vs. No Restraint		
. Absolute Frequency (D) = (A)-(B)	70.94	20.85
. Percentage Risk Reduction (E) = (D)/(A)	78%	18%
- Seat Belt vs. No Restraint		
. Absolute Frequency (F) = (A)-(C)	43.34	21.03
. Percentage Risk Reduction (G) = (F)/(A)	48%	22%
- Child Seat vs. Seat Belt		
. Absolute Frequency (H) = (C)-(B)	27.60	20.51
. Percentage Risk Reduction (I) = (H)/(C)	57%	29%

Note: 1. Frequency data are cited in terms of frequency of a serious injury event per 100 child involvements to permit easy comparison to percentage values.

\$ 1-40	0	
\$ 41-80	15	
\$ 81-160	32	
\$ 161-320	15	
\$ 321-640	5	
\$ 641-1280	6	
\$1281-2560	2	
\$over 2560	1	N = 76

Therefore, if the highest value which has the effect of biasing the mean significantly, was removed from the calculation, the mean value of maximum willingness to pay would be \$489. The largest number of people (42 out of 76 respondents) were willing to pay only between \$100 and \$200 at the most.

Comparing the maximum willingness to pay (average of \$489) with actual expenditures (average of \$72), it can be concluded that parents were willing to pay on average in order of 6 or 7 times more for a child safety seat for the purpose of reducing risk from injuries, than what they had actually spent. The majority of respondents were, however, willing to pay 1.5 to 3 times more than they actually spent.

Furthermore, parents were asked in the survey if they were willing to pay more, over and above the maximum they said they were willing to pay, for twice the protection, if such a device was available. Out of the 74 responding to the question, 19 (26 percent) said they were not willing to pay more. Of those (55) who were willing to pay more, the average amount they were willing to spend is \$205, for twice the protection, with the highest value being \$2000 and the lowest value being \$1. The majority (76 percent) were willing to pay only \$100 or less.

5.3.4 Expenditures per Unit Risk Reduction

It was determined from the survey that parents on the average spent \$72 on the purchase of a car seat which when used would result in a risk reduction of 12.6/1000. (See Section 5.3.1 for derivation of actual risk reduction). Thus the expenditure per unit risk reduction is calculated as \$5.71 per unit reduction in the frequency of sustaining serious injury from 1000 accident involvements.

Our survey also asked parents the maximum amount they were willing to pay for risk reduction. Excluding the highest value (for the reason mentioned earlier), the average maximum willingness to pay (1986\$) per unit perceived risk reduction was estimated at approximately \$40 per unit reduction in frequency of sustaining serious injury (\$489 divided by a perceived risk reduction of 12.6 events per 1000 involvements). Our survey found no apparent relationship between the users' maximum willingness to pay and their perceived risk reduction (see Appendix 5.3).

Among those parents who were willing to pay more for twice the protection (about 74 percent of the total) to their children, it is interpreted to mean that they were willing to pay more to see a risk factor of 3.4/1000 reduced to

1.7/1000. In other words, they were willing to pay more for an absolute reduction of 1.7/1000. The average value of willingness to pay for this amount of risk reduction, as determined from the survey and as presented earlier in Section 5.3.2, is \$205. This suggests a value of about \$120 per unit reduction in frequency of sustaining serious injury.

Based on this interpretation it would appear that respondents attach increasing value per marginal improvement in risk (i.e. \$40 per base unit reduction versus \$120 per incremental unit reduction). It is not clear, however, whether respondents interpreted the question as meaning an incremental halving of risk (i.e. 3.4/1000 to 1.7/1000) or a further absolute reduction of 12.6/1000, a situation which would not be technically possible given the initial risk level of 15.4/1000. In the latter instance it would appear that respondents attach a reducing value per marginal improvement in risk. The point highlights the importance of clearly differentiating between absolute and relative risk reduction.

5.4 Discussion

5.4.1 Reliability of Estimates

Our study findings were based on three main sources of information, as discussed in the previous section, namely previous research carried out in the United States and in Canada, reported accident statistics (1977-1985) compiled by the Ontario Ministry of Transportation and Communications and the survey carried out by The DPA Group in Calgary with 78 families with children under the age of 6 years.

(a) Traffic Accident Data-Based Analysis

Data derived from the first two sources were essentially compiled from similar original sources: accident reports either recorded by the various provincial/state police departments or government agencies in charge of record-keeping of accident reports. It follows that a number of situations or factors associated with this process could have critical implications on the degree of reliability of the final estimates of risk and risk reduction presented in this report. Of prime importance are the following factors:

- There is a large element of subjective interpretation on the part of the reporting officer who recorded the accident information, especially in deciding on the types of restraints used or not used by the victims or occupants when the accidents occurred. Research carried out by Transport Canada (Dalmotas, Dance, Gardner, Gutoskie and Smith 1984) found that many traffic accidents involved victims or occupants who over-reported the use of restraints, especially when children victims were involved.

- Allowance should be made for mistakes during recording or coding of information at the accident site, which would likely be higher under more stressful situations such as when accidents resulted in medical emergencies.

With respect to the first factor, the Transport Canada (Dalmotas, Dance, Gardner, Gutoskie and Smith 1984) study estimated that child restraint usage for the age group of 0-5 years in Ontario could be over-reported by up to 25 to 56 percent. This estimate was based on the comparison of the overall restraint usage rate over the period 1978-1980 in Ontario for this age group of children, reported in the accident-involved population (59.0%), with the restraint usage rate as observed in two roadside surveys, one in May 1978 and the other in May 1981, also for the same age group of children. The roadside surveys observed that usage rates were between 37.8 percent and 47.1 percent.

Over-reporting of child restraint usage means that the traffic accident data tend to understate the effectiveness of child restraints, because some of the non-restrained child victims would be recorded as restrained victims. As suggested in the recent Transport Canada (1984) study, there is little incentive for any individual to admit to being unrestrained, or to admit that children under his/her care were unrestrained, especially when faced with the possibility of incurring a fine for non-compliance with the law.

Thus, our study findings or estimates based on both U.S. and Canadian traffic accident data sources understate the factor of risk reduction associated with the use of child restraints, or the effectiveness of child restraints. However, it is not possible to determine the extent of the under-estimation, because the extent of misreporting is not known or has not been measured.

(b) Survey Data-Based Analysis

Based on a sample size (n) of 78 families and a population (N) of 24,700, it was estimated that the standard error (d) of the survey responses was .092 at a 90% confidence level.³ It was also estimated that if a higher precision target (or a smaller standard error) were desired, a larger sample size would be required. For example, if d = 0.050 was desired, the sample size (n) would have to be 268 families. Similarly, if d = 0.75 was desired, the sample size would have to be 120.

The ultimate sample size was determined by the number of volunteers willing to participate in our survey. This resulted in a non-random sample. The bias would be towards those who are interested in the subject of child restraints,

³ It was determined from Statistics Canada's data base that the number of families with children under the age of 6 years in Calgary in 1986 is 24,700, 1.4% higher than that in 1985. The 1.4% rate was the annual growth rate of families with children under 6 years of age between 1981 and 1985. The standard error estimate was based on the sampling techniques presented in Cochran (1963) p. 75: $n = no / (1 + no/N)$ where $no = f^2 PQ/d^2 = (1.645)^2 P(1-P)/d^2$; P = proportion of respondents choosing or not choosing a particular category of answer (binomial case); and d = standard error or precision target.

and those who were working parents. Daycare centres tend to represent a higher proportion of parents who work than the population at large. The sample may also tend to over-represent the child restraint users over the non-users. For example, all of the 78 respondents in our survey said they have or had used a child restraint when travelling with their child in their own motor vehicle. A 1984 survey on child car seat utilization in Calgary carried out by the Injury Research Unit of the University of Calgary (McGregor, Hodges and Read 1984) found 96.7 percent of the respondents had used an infant and/or child/convertible safety seat for their child. Also, in terms of frequency of use, our survey respondents showed an overwhelmingly high frequency of utilization of child restraints (96 percent), whereas in the University of Calgary survey cited earlier, only 54 percent of the respondents' children were always restrained. Thus, our survey did not represent the non-users' perceptions of risk and risk reduction associated with child restraint utilization, although this population may be quite small. Our survey also under-represents the infrequent users' values, although it may be safe to assume that the proportion of infrequent users among the total parent population is most likely less than 50 percent.

For these reasons, it is recommended that the results of our survey, especially on perceptions of risk and risk reduction and willingness to pay, be interpreted to represent the frequent users of child restraints, and not the non-users and infrequent users.

5.4.2 Roles, Responsibilities and Rationales for Risk Reduction

As mentioned in the introduction, child restraint use as a means of risk reduction has been promoted and encouraged by both the federal government through Transport Canada and the provincial governments in Canada. Enforcement of use has been the responsibility of the appropriate police forces of the various jurisdictions. Currently, nine out of the 10 provinces in Canada have passed child restraint legislation, rendering use of child restraints compulsory, although a few newly joined provinces have introduced age exemptions to the law. The purpose of this was to allow for an "easing-in" period until drivers became accustomed to the new law.

However, the ultimate responsibility and decision to use child restraints remains with the individual. Although available statistics suggest that child restraint use has been increasing noticeably in Canada, what is less publicized is the fact that further improvement of child restraint effectiveness in reducing risk of injuries and death is possible and is relatively easy to attain, through individual action in ensuring the proper and appropriate use of the child restraints.

There is a unanimous agreement among researchers and practitioners in the field that misuse or improper use of child restraints represents the prime factor in reducing the effectiveness of child restraints as a means of risk reduction. What this means is that the risk reduction estimates derived from reported accident reports on which virtually all existing research and studies were based have understated the true effectiveness of child restraints.

As mentioned earlier, Transport Canada carried out two National Child Restraint Use Surveys, one in 1984 and one in 1985. It was found in these surveys only about 55 percent in 1984 and 45 percent in 1985 of children under the age of 5 years were sitting in an appropriate restraint system for their age. "Appropriate" restraint systems were defined as follows: under 1 year of age - infant carrier or child seat; 1 to 4 - child seat, booster seat, seat belt. Of these children, only 43 percent in 1984 and 48 percent in 1985 were found to be wearing their appropriate restraints properly. Proper use was defined as follows: infant carrier - seat belt and shoulder harness fastened; child seat - seat belt and shoulder harness fastened and tether strap anchored; booster seat - seat belt fastened. It was found that the major sources of improper use were the failure to fasten the seat belt or to anchor the tether strap. As a result, only 24 percent in 1984 and 22 percent in 1985 of children were travelling safely in motor vehicles across Canada. Both Ontario and Alberta's percentages were slightly higher than the national average (25 percent) in 1985, but still very low.

These results suggest a very seriously high level of misuse or improper use among users of child restraints. Indeed some misuse can lead to injuries and death. As pointed out by many participants of the 1985 Safety Board's Symposium on Child Passenger Safety (U.S. National Transportation Safety Board 1985), if the true effectiveness of child restraints were to be realized, much attention is required to educate the public of the importance of the proper use of these devices, and the implications of their misuse or improper and inappropriate use.

As found in our survey of Calgary parents, all respondents considered the extent of protection the most important factor in their decisions in purchasing a child restraint. Child comfort and ease of access and/or use ranked as the distant second and third most important factors. Although other factors, including price, colour and appearance, durability of materials and child's visibility were mentioned as factors in the respondents' decision to purchase a car seat, they were generally rated much lower on a priority basis (see Appendix 5.3).

About 70 percent of these respondents were aware of the differences in the extent of protection afforded by different brands and models of car seats. Nonetheless, as high as 72 percent of all respondents who purchased a car seat did not compare price versus protection in their purchase decision. Many stated that since all car seats available for retail purchases have already been approved for safety, differences in price did not reflect differences in levels of protection.⁴

⁴ Nonetheless, the survey found that among those who purchased a car seat, 70 percent considered price either a moderately significant (62 percent) or a very significant (8 percent) factor in their purchase decision. About 30 percent did not consider price significant at all.

Only 6 percent of the survey respondents were not aware of the Alberta child restraint law.

Our survey results generally point out that the vast majority of parents already willingly take precautions to reduce the risk of injury and death to their children while riding in motor vehicles, and that most of them are willing to pay significantly more than what they had actually paid to achieve this.

While many parents were aware of their legal obligations, and were aware of the extent of protection child restraints afforded their children, as revealed by our survey, it was not clear if parents were aware of the implications of misuse of child restraints, or of any misuse they might be practising. As pointed out earlier in this section, experts in this field generally agree that this is perhaps the single most difficult problem that concerned authorities must deal with. It follows that attainment of higher protection or risk reduction for children while travelling in motor vehicles will continue to be a subject of research and debate.

It is also notable that their estimate of the extent of protection provided by a car seat is in close agreement with evidence from crash statistics. It is interesting that whereas parents judged child seats to be significantly more effective than seat belts, the Ontario data suggest that for the 0 to 5 year age group there is little empirical evidence of any difference in protection between the two devices.

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APPENDIX 5.1
Survey Questionnaire

SURVEY ON THE USE OF AND THE
WILLINGNESS-TO-PAY FOR CHILD RESTRAINT DEVICES
(AECB 14777 July, 1986)

		Variable Number
Interview Number		(1)
Phone Number		
Name of Volunteer Respondent		
Date of Interview	 d m y	
Interviewer	Code:	(2)
Interview Status	1 complete ☐ 2 partial ☐ 3 refusal ☐	(3)
Sex of Respondent	1 male ☐ 2 female ☐	(4)

Introduction:

Hello, my name is _____. I work with a consulting firm known as the DPA Group. We are conducting a non-commercial research survey on the use of car seats for children. We received your name as a volunteer respondent through your day care. Could you take about 10 minutes now to answer a few questions or would another interview time be more convenient?

1 Refused ☐
2 Agreed to participate ☐

Confirmed time for call-back:

day time

Page 1

Commence Interview

I would first like to emphasize that this interview is of a non-commercial nature, is totally confidential, and is part of a federal government study of consumer attitudes towards the purchase and use of car seats for children. In appreciation of your cooperation for completing this interview you will receive by mail a Safeway grocery purchase voucher in the amount of one dollar.

PART A Background Questions

A.1 How many children do you have in your household who are presently under the age of 6?

Number of children (5)

A.2 What are their ages?

(6-9)
under 1 1 2 3 4 5

A.3 Between 1980 and 1985, did your family own or otherwise regularly use a car, truck, or van for personal transport?

1. Yes (10)

2. No

If no, thank the respondent and terminate the interview with an explanation.

Page 2

A.4 Have you ever used an infant carrier or a child safety seat when travelling with your child in your vehicle?

1. Yes

☐

(11)

2. No

☐

GO TO PART C, Page 7

A.5 Have you used:

1. an infant carrier only

2. an infant carrier and child safety seat

3. a child safety seat only

☐☐☐

(12)

GO TO PART C, Page 7

PART B User Questions

B.1 Did you rent, purchase or receive the safety seat as a gift? (13)

- 1. rent ☐
- 2. purchase ☐
- 3. gift ☐
- 4. no resp. ☐

GO TO B.3, next page

B.2 Were you to purchase a car seat today which of the following factors would you consider in your decision to purchase? (14)

- | | Yes | No |
|----------------------------------|--------------------------|--------------------------|
| 1. price | ☐ | ☐ |
| 2. child comfort | ☐ | ☐ |
| 3. ease of access and/or use | ☐ | ☐ |
| 4. extent of protection provided | ☐ | ☐ |
| 5. color and appearance | ☐ | ☐ |
| 6. durability of materials | ☐ | ☐ |
| Other | | |
| 7. _____ | ☐ | ☐ |
| 8. _____ | ☐ | ☐ |

Which factor would you consider: (15)

- 1. most important ☐
- 2. second most important ☐
- 3. third most important ☐

GO TO B.4, Page 6

B.3 a) Was the seat purchased new or used? (16)

- 1. new ☐
- 2. used ☐
- 3. no response ☐

b) Do you recall approximately when it was purchased? (17)

- 1. year ☐ 1 ☐ 9 ☐ ☐ ☐
- 2. no response ☐

c) Do you recall the approximate price paid for the car seat? (18)

- 1. approx. price \$ ☐ ☐ ☐ ☐
- 2. no response ☐

d) Which of the following factors did you consider in your decision to purchase your car seat? (19-26)

	Yes	No
1. price	☐	☐
2. child comfort	☐	☐
3. ease of access and use	☐	☐
4. extent of protection provided	☐	☐
5. color and appearance	☐	☐
6. durability of materials	☐	☐
Other		
7. _____	☐	☐
8. _____	☐	☐

e) Which of the above factors would you consider: (27-29)

- 1. most important ☐
- 2. second most important ☐
- 3. third most important ☐

(Note: Use numbers from question d) above.)

- f) Overall, how significant a factor was price in your decision? (30)

- 1. not significant at all ☐
- 2. moderately significant ☐
- 3. very significant ☐
- 4. do not know ☐

- g) At the time of purchase were you aware of any differences in the extent of protection provided by different brands or models of car seat? (31)

- 1. Yes ☐
- 2. No ☐
- 3. Do not know ☐

If yes how did you become aware of these differences? (32)

- h) Did you compare price versus protection in your purchase decision? (33)

- 1. Yes ☐
- 2. No ☐
- 3. Do not know ☐

Comments for Question h)

Page 6

B.4 Overall, how often have you used the child car seat when (34)
travelling with your child in your vehicle?

4

90-100	1	always or almost always	☐
56-89	2	more than half the time	☐
45-55	3	about half the time	☐
11-44	4	less than half the time	☐
1-10	5	hardly ever	☐

(Check one)

GO TO PART D, Page 8

PART C Non-User Questions

C.1 What were the main reasons for your not using a child (35-40)
car seat before 1986?

- | | Yes | No |
|---|--------------------------|--------------------------|
| 1. car seats were too expensive | ☐ | ☐ |
| 2. car seats were uncomfortable
for the child | ☐ | ☐ |
| 3. car seats were inconvenient to use | ☐ | ☐ |
| 4. did not believe car seats could
reduce risk of injury | ☐ | ☐ |
| Other | | |
| 5. _____ | | |
| 6. _____ | | |

C.2 Which of the above reasons did you consider: (41-43)

- | | |
|--------------------------|--------------------------|
| 1. most important | ☐ |
| 2. second most important | ☐ |
| 3. third most important | ☐ |

(Note: Use numbers from C.1)

PART D Willingness-to-Pay Questions

D.1 We would like to obtain your perceptions on how effective (44)
you believe child car seats are in reducing the risk of
serious injury or death to children in the event of an
accident, as compared to a child using no restraint (i.e.
neither lap belt or car seat). In your view do child car
seats result in:

1. no reduction
2. very little reduction
3. moderate reduction
4. large reduction

... in risk in the event of an accident.

D.2 Consider the following example. Take 100 car accidents, (45)
each of which involves a car travelling at 60 km per hour
colliding headon into a stationary object, and in which
100 children under 40 lbs are involved. In your judgement
what percentage of the children would receive serious
injuries if they are:

- a) totally unrestrained (i.e. with neither seat
belt or car seat) in the back seat of the car %
- b) restrained in a car seat in the back of the
car %
- c) restrained by a lap belt in the back seat of
the car %

D.3 If you were to make a purchase of a child car seat today (46)
what would be the maximum amount that you would be
willing-to-pay were there only one brand and model of seat
on the market (that is, you have no other choice)? Please
give your best estimate.

\$

D.4 If a car seat were to be available which provided twice (47)
the protection of existing seats would you be willing-to-
pay more than the maximum amount you identified in the
previous question?

1. yes ☐

2. no ☐

3. don't know ☐

GO TO
D.6

D.5 If yes, could you provide an estimate of approximately (48)
how much more you would be willing-to-pay for twice the
protection? (49)

1. yes ☐ amount \$

2. no ☐

D.6 Are you aware that it has become law in Alberta that (50)
children born after Dec. 31, 1984 have to be in a child
restraint device when travelling in a motor vehicle?

1. yes ☐

2. no ☐

Thank you very much for your cooperation in completing this survey. In
order that we may send you your \$5 grocery voucher could you please give
us your mailing address?

Address:

Comments:

APPENDIX 5.2

Detailed Accident Data, Ontario

1977 - 1985

Number of Involvements by Children
Ages 0-5 Years by Severity of Injuries
and by Restraint Usage

1977

Restraint Usage	Injury Severity					
	None	Minimal	Minor	Major	Fatal	Total
No Restraint	7639 (82.1)	788 (8.5)	766 (8.2)	98 (1.05)	13 (0.14)	9304 (99.99)
Child Restraint	1697 (91.0)	118 (6.3)	43 (2.3)	6 (0.30)	1 (0.05)	1865 (99.95)
Seat Belt	6536 (92.1)	330 (4.6)	210 (3.0)	20 (0.28)	1 (0.01)	7097 (99.99)
Risk Reduction Index						
			<u>Major</u>	<u>Fatal</u>		
No Restraint vs. Child Restraint			71%	0%		
No Restraint vs. Seat Belt			73%	100%		

Note: Numbers in brackets indicate percentages of total. Totals do not always add up to 100% due to rounding.

1978

Restraint Usage	Injury Severity					
	None	Minimal	Minor	Major	Fatal	Total
No Restraint	5395 (79.3)	758 (11.1)	531 (7.8)	107 (1.57)	15 (0.22)	6806 (99.99)
Child Restraint	1662 (91.3)	95 (5.2)	55 (3.0)	5 (0.27)	4 (0.22)	1821 (99.99)
Seat Belt	5999 (90.3)	417 (6.3)	211 (3.2)	18 (0.27)	0 (0.00)	6645 (100.07)
Risk Reduction Index						
			<u>Major</u>	<u>Fatal</u>		
No Restraint vs. Child Restraint			83%	0%		
No Restraint vs. Seat Belt			83%	100%		

1979

Restraint Usage	Injury Severity					
	None	Minimal	Minor	Major	Fatal	Total
No Restraint	5311 (80.1)	732 (11.0)	474 (7.1)	103 (1.55)	14 (0.21)	6634 (99.96)
Child Restraint	1849 (90.8)	117 (5.7)	62 (3.0)	7 (0.34)	2 (0.10)	2037 (99.94)
Seat Belt	6199 (90.4)	430 (6.3)	201 (2.9)	22 (0.32)	2 (0.03)	6854 (99.95)
Risk Reduction Index						
				<u>Major</u>	<u>Fatal</u>	
No Restraint vs. Child Restraint				78%	52%	
No Restraint vs. Seat Belt				79%	86%	

1980

Restraint Usage	Injury Severity					
	None	Minimal	Minor	Major	Fatal	Total
No Restraint	4905 (85.5)	711 (12.4)	11 (0.2)	92 (1.60)	17 (0.30)	5736 (100.00)
Child Restraint	2144 (99.1)	9 (0.4)	10 (0.5)	0 (0.00)	1 (0.05)	2164 (100.05)
Seat Belt	6095 (89.2)	495 (7.2)	217 (3.2)	27 (0.39)	2 (0.03)	6836 (100.02)
Risk Reduction Index						
				<u>Major</u>	<u>Fatal</u>	
No Restraint vs. Child Restraint				100%	83%	
No Restraint vs. Seat Belt				76%	90%	

1981

Restraint Usage	Injury Severity					
	None	Minimal	Minor	Major	Fatal	Total
No Restraint	4157 (77.8)	666 (12.5)	436 (8.2)	66 (1.24)	19 (0.36)	5344 (100.1)
Child Restraint	2322 (92.2)	128 (5.1)	62 (2.5)	4 (0.16)	1 (0.04)	2517 (100.00)
Seat Belt	6410 (89.8)	502 (7.0)	197 (2.8)	27 (0.38)	2 (0.03)	7138 (100.01)
Risk Reduction Index						
			<u>Major</u>		<u>Fatal</u>	
No Restraint vs. Child Restraint			87%		89%	
No Restraint vs. Seat Belt			69%		92%	

1982

Restraint Usage	Injury Severity					
	None	Minimal	Minor	Major	Fatal	Total
No Restraint	3197 (77.4)	473 (11.5)	373 (9.0)	79 (1.91)	8 (0.19)	4130 (100.00)
Child Restraint	2418 (92.7)	122 (4.7)	62 (2.4)	6 (0.23)	0 (0.00)	2608 (100.03)
Seat Belt	6219 (90.3)	446 (6.5)	199 (2.9)	20 (0.29)	1 (0.01)	6885 (100.02)
Risk Reduction Index						
			<u>Major</u>		<u>Fatal</u>	
No Restraint vs. Child Restraint			88%		100%	
No Restraint vs. Seat Belt			85%		95%	

1983

Restraint Usage	Injury Severity					
	None	Minimal	Minor	Major	Fatal	Total
No Restraint	6728 (91.7)	293 (4.0)	246 (3.3)	67 (0.91)	6 (0.08)	7340 (99.99)
Child Restraint	3128 (92.7)	159 (4.7)	72 (2.1)	16 (0.47)	0 (0.00)	3375 (99.97)
Seat Belt	5934 (89.7)	438 (6.6)	213 (3.2)	30 (0.45)	1 (0.02)	6616 (99.97)
Risk Reduction Index						
				<u>Major</u>	<u>Fatal</u>	
No Restraint vs. Child Restraint				48%	100%	
No Restraint vs. Seat Belt				51%	75%	

1984

Restraint Usage	Injury Severity					
	None	Minimal	Minor	Major	Fatal	Total
No Restraint	1473 (73.6)	282 (14.1)	193 (9.6)	46 (2.30)	8 (0.40)	2002 (100.00)
Child Restraint	4939 (92.1)	257 (4.8)	145 (2.7)	16 (0.30)	3 (0.06)	5360 (99.96)
Seat Belt	7020 (90.2)	501 (6.4)	234 (3.0)	25 (0.32)	1 (0.01)	7781 (99.93)
Risk Reduction Index						
				<u>Major</u>	<u>Fatal</u>	
No Restraint vs. Child Restraint				87%	85%	
No Restraint vs. Seat Belt				86%	98%	

1985

Restraint Usage	Injury Severity					
	None	Minimal	Minor	Major	Fatal	Total
No Restraint	1333 (65.6)	422 (20.8)	227 (11.1)	36 (1.77)	13 (0.64)	2031 (99.91)
Child Restraint	5148 (90.8)	306 (5.4)	184 (3.2)	27 (0.48)	2 (0.04)	5667 (99.92)
Seat Belt	7261 (88.2)	638 (7.7)	294 (3.6)	41 (0.50)	2 (0.02)	8236 (100.02)
<u>Risk Reduction Index</u>						
			<u>Major</u>	<u>Fatal</u>		
No Restraint vs. Child Restraint			73%	94%		
No Restraint vs. Seat Belt			72%	97%		

For Children Ages 0-2

1984

Restraint Usage	Injury Severity					
	None	Minimal	Minor	Major	Fatal	Total
No Restraint	617 (80.3)	80 (10.4)	55 (7.2)	12 (1.56)	4 (0.52)	768 (99.98)
Child Restraint	3865 (92.6)	186 (4.5)	107 (2.6)	14 (0.34)	3 (0.07)	4175 (100.11)
Seat Belt	1475 (91.6)	89 (5.5)	43 (2.7)	4 (0.25)	0 (0.00)	1611 (100.05)

1985

Restraint Usage	Injury Severity					
	None	Minimal	Minor	Major	Fatal	Total
No Restraint	549 (79.1)	57 (8.2)	73 (10.5)	10 (1.44)	5 (0.72)	694 (99.96)
Child Restraint	4098 (91.4)	235 (5.2)	129 (2.9)	23 (0.51)	1 (0.02)	4486 (100.03)
Seat Belt	1541 (90.0)	113 (6.6)	47 (2.7)	11 (0.64)	0 (0.00)	1712 (94.94)

Risk Reduction Index

		<u>Major</u>	<u>Fatal</u>
No Restraint vs. Child Restraint	1984	78%	87%
	1985	65%	97%
No Restraint vs. Seat Belt	1984	84%	100%
	1985	56%	100%

For Children Ages 3-5

1984

Restraint Usage	Injury Severity					
	None	Minimal	Minor	Major	Fatal	Total
No Restraint	856 (69.4)	202 (16.4)	138 (11.2)	34 (2.76)	4 (0.32)	1234 (100.08)
Child Restraint	1074 (90.6)	71 (6.0)	38 (3.2)	2 (0.17)	0 (0.00)	1185 (99.97)
Seat Belt	5545 (89.9)	412 (6.7)	191 (3.1)	21 (0.34)	1 (0.02)	6170 (100.06)

1985

Restraint Usage	Injury Severity					
	None	Minimal	Minor	Major	Fatal	Total
No Restraint	784 (58.6)	365 (27.3)	154 (11.5)	26 (1.94)	8 (0.60)	1337 (99.94)
Child Restraint	1050 (88.9)	71 (6.0)	55 (4.7)	4 (0.34)	1 (0.08)	1181 (100.02)
Seat Belt	5720 (87.7)	525 (8.0)	247 (3.8)	30 (0.46)	2 (0.03)	6524 (99.99)

Risk Reduction Index

		<u>Major</u>	<u>Fatal</u>
No Restraint vs. Child Restraint	1984	94%	100%
	1985	82%	87%
No Restraint vs. Seat Belt	1984	88%	94%
	1985	76%	95%

APPENDIX 5.3

**Survey Results
(Selected Analysis)**

TABLE I

PERCEIVED RELATIVE RISK REDUCTION

CASE UNRESTRAINED CHILD SEAT				CHILD SEAT EFFECTIVENESS				OVER SEAT BELT			
(A)	(B)	(C)	(D) = (A) - (B)	(E) = (D) / (A)	(F) = (A) - (C)	(G) = (F) / (A)	(H) = (E) - (B)	(I) = (H) / (E)			
1	100	10	25	0.90	75	0.25	15	0.60			
2	65	5	8	0.92	57	0.88	3	0.38			
3	90	25	40	0.72	50	0.56	15	0.38			
4	40	10	25	0.75	15	0.18	15	0.60			
5	100	20	60	0.80	40	0.40	40	0.67			
6	95	5	6	0.95	95	1.00	-5	0.00			
7	90	33	70	0.63	20	0.22	37	0.53			
8	100	8	68	0.92	32	0.32	60	0.80			
9	99	50	75	0.49	24	0.24	25	0.13			
10	99	20	50	0.80	49	0.49	30	0.60			
11	80	25	60	0.69	20	0.25	35	0.58			
12	99	25	50	0.75	49	0.49	25	0.50			
13	100	30	55	0.70	45	0.45	25	0.45			
14	100	70	55	0.30	45	0.45	-15	-0.27			
16	65	20	40	0.69	25	0.38	20	0.50			
17	100	20	50	0.80	50	0.50	30	0.60			
18	100	50	55	0.50	45	0.45	5	0.09			
19	100	10	23	0.90	77	0.77	13	0.57			
20	100	0	50	1.00	50	0.50	50	1.00			
21	100	2	100	0.98	0	0.00	98	0.98			
22	100	75	50	0.25	50	0.50	-25	-0.50			
23	95	15	35	0.84	60	0.63	20	0.57			
24	95	15	30	0.84	65	0.68	15	0.50			
25	100	20	30	0.80	70	0.70	10	0.33			
26	76	9	30	0.88	46	0.61	21	0.70			
27	100	2	65	0.98	35	0.35	63	0.97			
28	100	25	75	0.75	25	0.25	50	0.67			
29	100	8	60	0.92	40	0.40	52	0.87			
30	98	5	40	0.95	58	0.59	35	0.88			
31	100	8	15	0.92	85	0.85	7	0.47			
32	99	29	60	0.71	39	0.39	31	0.52			
33	100	10	20	0.90	80	0.80	10	0.50			
34	100	25	75	0.75	25	0.25	50	0.67			
35	100	5	50	0.95	50	0.50	45	0.90			
36	70	13	40	0.81	30	0.43	27	0.68			
37	100	5	50	0.95	50	0.50	45	0.90			

TABLE I

PERCEIVED RELATIVE RISK REDUCTION

CASE UNRESTRAINED CHILD SEAT SEAT BELT CHILD SEAT EFFECTIVENESS SEAT BELT EFFECTIVENESS				CHILD SEAT EFFECTIVENESS OVER SEAT BELT				
(A)	(B)	(C)	(D)=(A)-(B)	(E)=(D)/(A)	(F)=(A)-(C)	(G)=(F)/(A)	(H)=(C)-(D)	(I)=(H)/(C)
38	95	15	80	0.84	55	0.58	25	0.63
39	100	2	98	0.98	65	0.65	33	0.94
40	100	3	97	0.97	70	0.70	27	0.90
42	80	40	40	0.50	5	0.06	35	0.47
43	100	30	70	0.70	25	0.25	45	0.60
44	75	0	75	1.00	50	0.67	25	1.00
45	100	60	40	0.40	15	0.15	25	0.29
46	100	65	35	0.35	20	0.20	15	0.19
47	90	20	70	0.78	60	0.67	10	0.33
48	80	10	70	0.88	50	0.63	20	0.67
49	90	45	45	0.50	45	0.50	0	0.00
50	70	0	70	1.00	65	0.93	5	1.00
51	100	30	70	0.70	45	0.45	25	0.45
52	40	5	35	0.88	35	0.88	0	0.00
53	84	50	34	0.40	14	0.17	20	0.29
54	100	50	50	0.50	30	0.30	20	0.29
55	100	20	80	0.80	40	0.40	40	0.67
56	100	30	70	0.70	50	0.50	20	0.40
57	80	50	30	0.38	10	0.13	20	0.29
58	20	3	17	0.85	6	0.30	11	0.79
59	78	5	73	0.94	68	0.87	5	0.50
60	98	5	93	0.95	63	0.64	20	0.86
61	80	40	40	0.50	10	0.13	30	0.43
62	100	35	65	0.65	45	0.45	20	0.76
63	100	25	75	0.75	45	0.45	30	0.55
64	95	10	85	0.89	75	0.79	10	0.50
65	90	20	70	0.78	30	0.33	40	0.67
66	80	15	65	0.81	50	0.63	15	0.50
67	98	25	73	0.74	58	0.59	15	0.38
68	100	75	25	0.25	25	0.25	50	0.67
69	100	10	90	0.90	50	0.50	40	0.80
70	100	10	90	0.90	55	0.55	35	0.78
71	78	11	65	0.83	38	0.49	27	0.68
72	85	15	70	0.82	35	0.41	35	0.70
73	90	15	75	0.83	10	0.11	65	0.81
74	100	0	100	1.00	50	0.50	50	1.00

TABLE I

PERCEIVED RELATIVE RISK REDUCTION

CASE UNRESTRAINED		CHILD SEAT		SEAT BELT		CHILD SEAT EFFECTIVENESS		SEAT BELT EFFECTIVENESS		CHILD SEAT EFFECTIVENESS OVER SEAT BELT	
(A)	(B)	(C)	(D)=(A)-(B)	(E)=(D)/(A)	(F)=(A)-(C)	(G)=(F)/(A)	(H)=(C)-(B)	(I)=(H)/(C)	(J)=(H)/(C)	(K)=(H)/(C)	(L)=(H)/(C)
75	100	0	85	100	15	0.15	85	1.00	85	1.00	1.00
76	99	5	30	94	69	0.70	25	0.83	25	0.83	0.83
77	85	15	55	70	30	0.35	40	0.73	40	0.73	0.73
78	100	20	80	80	10	0.10	70	0.70	70	0.70	0.70
79	100	10	70	90	80	0.80	10	0.50	10	0.50	0.50
NEAN	91.10	20.17	47.77	70.94	43.34	0.48	27.60	0.57	27.60	0.57	0.57
STDEV	15.19	17.45	22.04	20.85	21.63	0.27	20.51	0.29	20.51	0.29	0.29

Table 11

EXPENDITURES VS. PERMITTED RISK REDUCTION

LINE	PHILL OF LAW SLAT (81Y86) (A)	PERMITTED RISK REDUCTION (B)	LINE	PHILL OF LAW SLAT (81Y86) (A)	PERMITTED RISK REDUCTION (B)	LINE	PHILL OF LAW SLAT (81Y86) (A)	PERMITTED RISK REDUCTION (B)
2	51	92.00	30	90	84.00	79	90	90.00
4	28	75.00	34	80	98.00			
5	96	80.00	40	104	97.00	80M	72.03	77.49
6	70	95.00	43	72	70.00	510LV	24.25	10.65
7	74	65.00	45	75	40.00			
8	76	92.00	46	76	55.00			
9	55	49.00	47	87	78.00			
10	62	80.00	48	156	88.00			
11	65	69.00	49	64	50.00			
12	93	75.00	51	77	70.00			
13	28	70.00	52	71	88.00			
14	72	30.00	53	65	40.00			
15	72	69.00	54	101	50.00			
16	72	80.00	55	65	80.00			
17	53	50.00	56	57	70.00			
18	57	90.00	57	52	38.00			
19	136	100.00	58	69	85.00			
20	88	98.00	60	65	95.00			
21	41	25.00	62	85	65.00			
22	52	84.00	63	72	75.00			
23	71	88.00	64	69	89.00			
24	21	80.00	65	90	78.00			
25	64	88.00	66	80	81.00			
26	74	98.00	68	48	75.00			
27	55	75.00	70	95	90.00			
28	56	92.00	71	74	85.00			
29	69	95.00	72	96	85.00			
30	106	92.00	74	80	100.00			
31	65	75.00	75	74	100.00			
32	74	95.00	76	106	95.00			
33	50	81.00	77	70	85.00			
34	86	95.00	78	74	80.00			

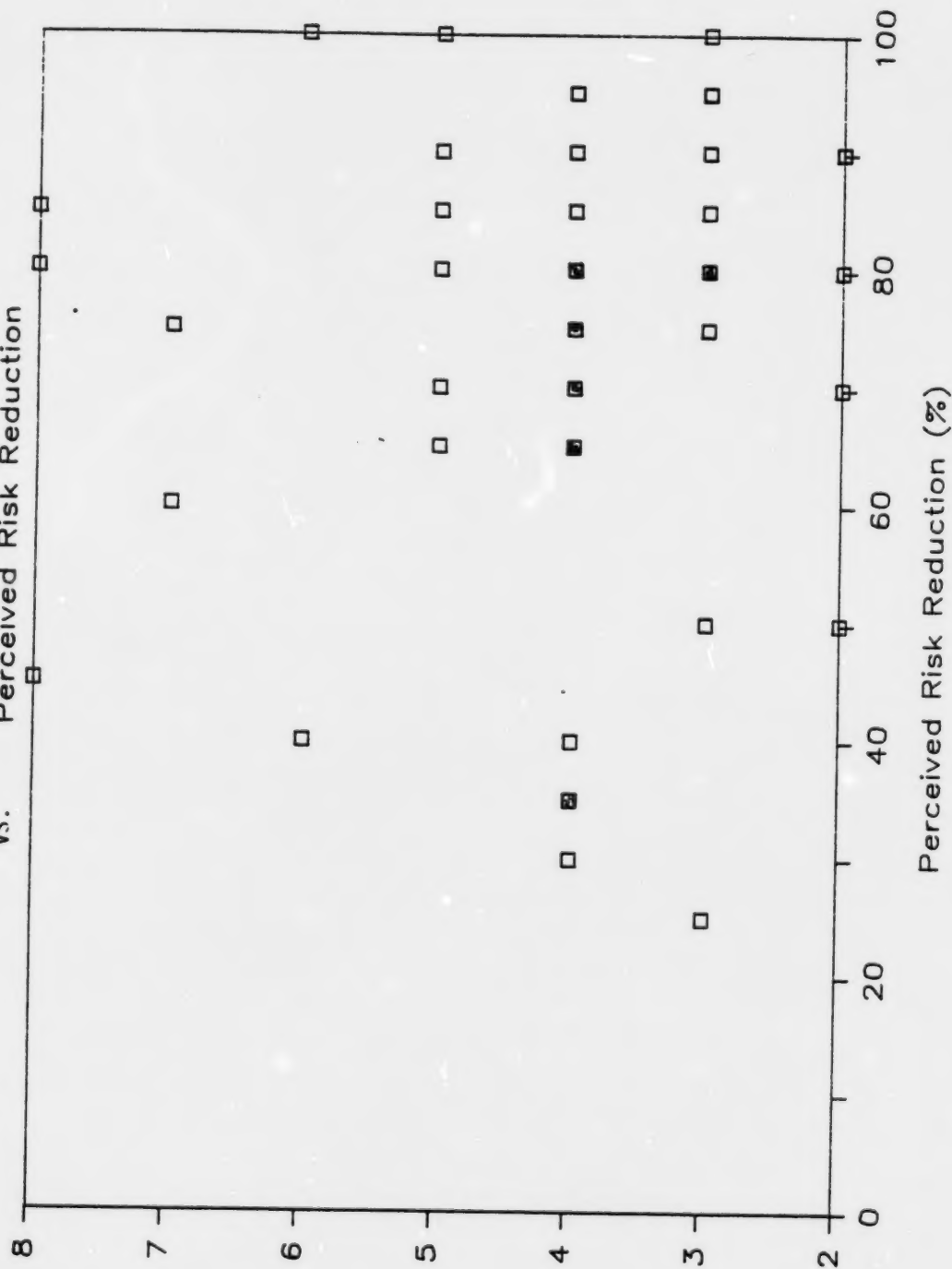
Table III

WILL INDEBT TO PAY VS PERCEIVED RISK REDUCTION

Case	WILL INDEBT TO PAY FOR		PERCEIVED RISK REDUCTION		WILL INDEBT TO PAY FOR		PERCEIVED RISK REDUCTION	
	Case	(a)	(b)	(c)	Case	(a)	(b)	(c)
2	2	80	92.00	38	200	84.00	84.00	17.53
4	4	2000	75.00	39	150	98.00	98.00	18.39
5	5	200	80.00	40	300	97.00	97.00	
6	6	150	95.00	43	500	70.00	70.00	
7	7	2000	63.00	45	1000	40.00	40.00	
8	8	500	92.00	46	250	35.00	35.00	
9	9	4000	49.00	47	200	78.00	78.00	
10	10	150	80.00	48	500	88.00	88.00	
11	11	300	69.00	49	100	50.00	50.00	
12	12	150	75.00	51	200	70.00	70.00	
13	13	60	70.00	52	150	88.00	88.00	
14	14	300	30.00	53	200	40.00	40.00	
16	16	200	69.00	54	75	50.00	50.00	
17	17	180	80.00	55	200	80.00	80.00	
18	18	100	50.00	56	350	70.00	70.00	
19	19	150	90.00	57	250	38.00	38.00	
20	20	1000	100.00	58	20000	85.00	85.00	
21	21	250	98.00	60	150	95.00	95.00	
22	22	150	25.00	62	600	65.00	65.00	
23	23	90	84.00	63	500	75.00	75.00	
24	24	125	84.00	64	240	89.00	89.00	
25	25	75	80.00	65	180	78.00	78.00	
26	26	250	88.00	66	175	81.00	81.00	
27	27	200	90.00	70	150	90.00	90.00	
28	28	105	75.00	71	100	85.00	85.00	
29	29	80	92.00	72	600	82.00	82.00	
30	30	150	92.00	74	150	100.00	100.00	
31	31	200	92.00	75	501	100.00	100.00	
34	34	2000	75.00	76	150	95.00	95.00	
35	35	95	95.00	77	200	82.00	82.00	
36	36	105	81.00	78	4000	80.00	80.00	
37	37	175	95.00	79	500	90.00	90.00	

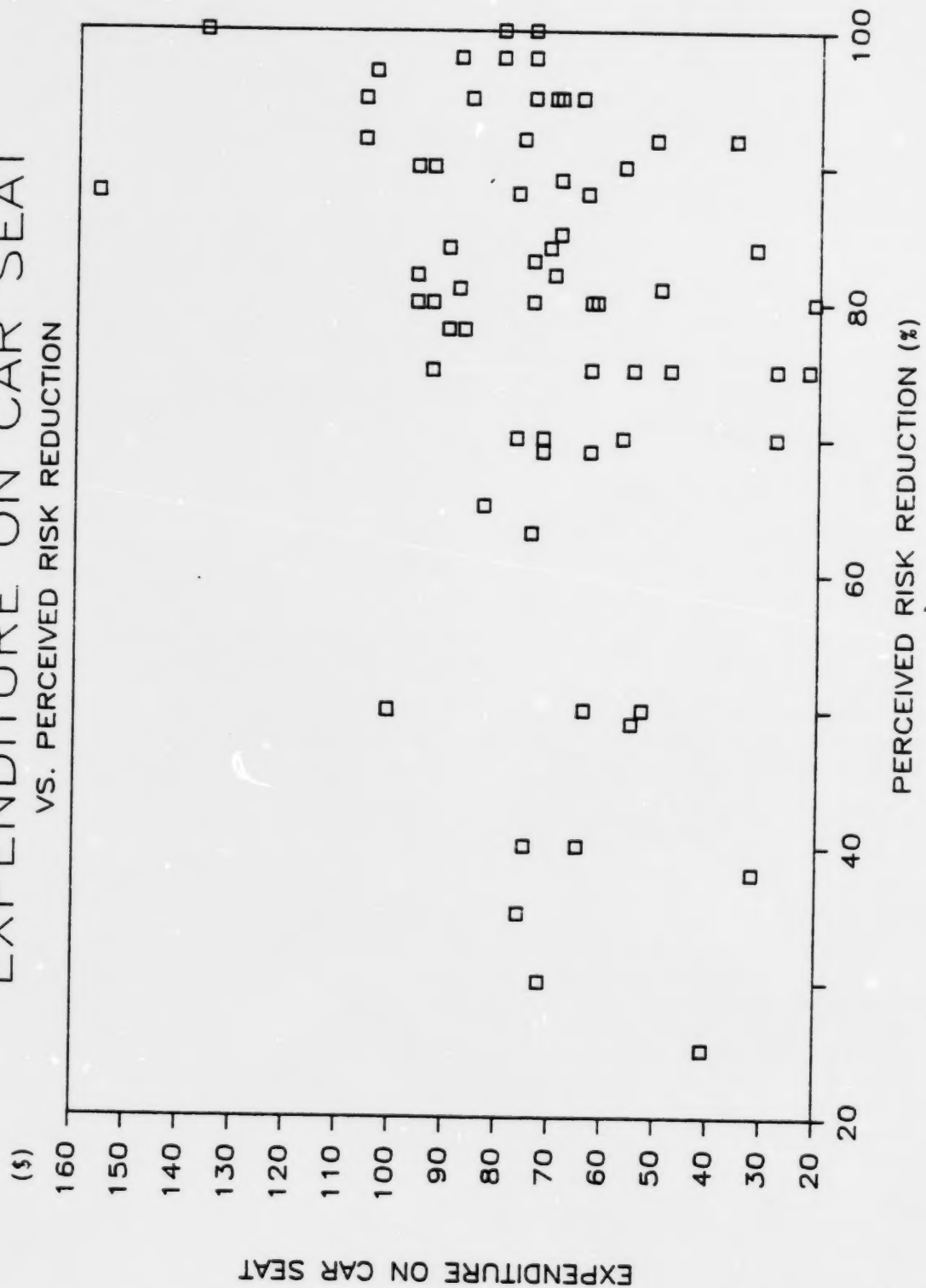
WILLINGNESS TO PAY

vs. Perceived Risk Reduction



- Willingness to Pay (\$)
- 1 = 1-40
 - 2 = 41-80
 - 3 = 81-160
 - 4 = 161-320
 - 5 = 321-640
 - 6 = 641-1280
 - 7 = 1281-2560
 - 8 = over 2560

EXPENDITURE ON CAR SEAT VS. PERCEIVED RISK REDUCTION



Appendix 5.4 General Evidence of Child Seat Effectiveness from the Literature

In the area of child restraint effectiveness research, the United States has produced the most extensive results. Since 1970, many U.S. studies have attempted to quantify the relationship between risk reduction and use of child restraints and/or seating position. All these studies were based on reported accident statistics. Among these, three studies specifically focussed on the effectiveness of child restraints. The first is Scherz's 1981 study which reviewed 10 years of accident data compiled by the Washington State Patrol, and which comprised approximately 39,500 children four years of age and under. The second study was conducted by the Centre for the Environment and Man under contract to the U.S. Department of Transportation (Knoop, Costenoble, Ball and Northrop 1980) which is also based on mass accident data. The sample sizes varied from 21,837 cases from New York State to 3,766 cases from Idaho. All cases involved children four years or under. The third study was a comprehensive review of all effectiveness studies by Kahane, Kosar and Chi (1983). Their conclusions on the effectiveness of child restraints in terms of the percentage reduction of risk of fatal and serious injury are summarized as follows:

Scherz	93% (fatal injury); 78% (serious injury)
Knoop, Costenoble & Northrop	27.5% (overall fatal and serious injury in New York, State only)
Kahane, Kosar & Chi	25-30% (overall injury); 40-50% (fatal injury)

While the above studies suggest a wide range of reduction indices, they all conclusively support evidence that child restraint did lead to reduced risk.

There have also been attempts in Canada to measure the effectiveness of child restraints on risk reduction. One recent study (Dalmotas, Dance, Gardner, Gutoskie and Smith 1984) reported the following estimates:

Alberta	75% (overall fatal and serious injury)
Ontario	62% (fatal injury only)

The above estimates were based on 1978-1980 data derived from provincial police reports on accident data. The difference between these Canadian estimates and the above U.S. estimates is that the Canadian estimates were for all restraint systems used by the child occupant age zero to four years involved in a reportable accident. This means that seat belts were included. The U.S. estimates were for child restraints only. Nonetheless, it is safe to conclude that there is evidence, based on Canadian sources, that child restraints reduced risk of serious and fatal injuries.